

DEPARTMENT OF ENERGY

THE APPLICATION OF MONITORING & TARGETING TO ENERGY MANAGEMENT



ENERGY EFFICIENCY SERIES
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HER MAJESTY'S STATIONERY OFFICE

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THE APPLICATION OF MONITORING & TARGETING TO ENERGY MANAGEMENT

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Department of Energy
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Foreword

**By The Rt Hon Cecil Parkinson MP
Secretary of State for Energy**

The use of energy is part of our every day life, particularly at work. If we make better use of our energy resources it goes without saying that we will reduce our energy costs, as well as increasing profits and adding to the national wealth. All of us who use energy – whether for heating and lighting buildings, for providing transport, in commerce, industry or the public sector – need to be aware of how to control our energy and use it more effectively.

The monitoring and targeting programme initiated by the Department of Energy in 1980 has shown that substantial improvements in energy use can be achieved by a more disciplined approach to energy management. Monitoring and targeting systems have been developed for many sectors of industry and commerce. The benefits to the firms taking part have been substantial.

This general guide has been prepared to make the principles and practice of monitoring and targeting more widely known. I recommend it to senior executives with responsibility for energy costs, as well as to plant managers and anyone with control over the use of energy in industry, commerce, and the public sector. I also recommend it to anyone who aspires to be an effective resource manager. I hope it will prove a source of advice on good practice for teacher and student alike.



Secretary of State for Energy

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Preface

This general guide has been prepared to show how monitoring and targeting can control energy use and improve the efficiency with which energy is used in different sectors of the national economy. It is based on the results of work carried out, under the Energy Efficiency Office Monitoring and Targeting Programme, on the development of practical energy management systems for use in manufacturing industry, commerce and the public sector. The development of these systems has covered the use of energy in a multitude of activities and has depended on the varied and special expertise of all those involved in this wide-ranging programme.

The principles of monitoring and targeting are described together with the steps which have to be taken to set up monitoring and targeting as an integral part of an existing management organization. Procedures are given for monitoring energy use, defining standards and targets, reporting results and reviewing progress. These procedures which have been developed and tested in working environments are illustrated with examples of their practical application.

Finally, an account is given of the improvements of performance in the use of energy and the other benefits which can be gained through energy monitoring and targeting.

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1. Introduction

Compared with other industrialised countries, the United Kingdom is fortunate in its energy reserves. But if energy is used carelessly and inefficiently, a needless burden has to be carried by the national economy: the costs of goods and services are unnecessarily increased and industries become less competitive.

In 1984, the total expenditure on energy by final users in the UK was over £36 billion corresponding to 11.5% of the Gross Domestic Product. The 20% reduction in this energy cost which could be achieved through improvements in the way energy is used would correspond to a saving of some £7 billion per annum. This would not only mean savings in energy costs to individual consumers, it would also lead to increases in the profitability and competitiveness of our industries. It could also reduce the capital investment needed to meet future energy demands.

The massive increase in oil prices in 1973 was followed by a decrease in the annual energy consumption in relation to GDP from 1.9 tonnes of coal equivalent per £1000 GDP (at 1980 factor cost) to 1.5 tonnes in 1984 (1). This reduction was, in part, related to changes in the pattern of industrial activity and the lower levels of production in the more energy-intensive industries. At the same time, improvements were also made in the effective use of energy, and many private businesses and public organizations made significant progress in reducing their energy costs. But although there were these improvements following the increase in energy prices, there is firm evidence that much more could be done (2).

The main barriers to improvement appear to lie in management attitudes, practices and policies. There is often a lack of knowledge of what can be done to improve energy management, the potential benefits are not perceived, and there is a lack of technical skill and understanding to carry out the necessary improvements. Further barriers are the views that little can be done with existing constraints on capital expenditure, that energy costs are a small proportion of total costs and that other areas are more deserving of management attention.

To overcome these barriers, economic and practical systems of energy management need to be developed and their successful application demonstrated.

Energy Efficiency Office — M & T Programme

<i>Sector</i>	<i>System development contractor</i>	<i>Trade Association</i>
Paper and Board ✓	The British Paper & Board Industry Federation	The British Paper & Board Industry Federation
Textile Finishing ✓	Shirley Institute	British Textile Employers' Association Knitting Industries' Federation Ltd
Iron Founding ✓	British Foundry Association	British Foundry Association
Steel Industry (Private Sector) ✓	BNF Metals Technology Centre	The British Independent Steel Producers Association
Pottery ✓	British Ceramic Research Association Ltd	British Ceramic Manufacturers Association
Clay Bricks ✓	British Ceramic Research Association Ltd	National Federation of Clay Industries
Drop Forging ✓	Drop Forging Research Association	British Forging Industry Association
Steel Castings ✓	Steel Castings Research and Trade Association	Steel Castings Research and Trade Association
Timber Saw Milling ✓	Timber Research and Development Association	British Timber Merchants Association National Saw Milling Association Home Timber Merchants Association
Food Processing (I and II) ✓	British Food Manufacturing Industries Research Association	Food Manufacturers Federation FDF? Dairy Trade Federation Chocolate Cocoa and Confectionery Alliance
Soft Drinks ✓	National Association of Soft Drinks Manufacturers Limited	National Association of Soft Drinks Manufacturers Limited Now B3DA?
Canning ✓	Campden Food Preservation Research Association	British Food Canning Association Food Manufacturers Federation Bacon & Meat Manufacturers Association
Chemicals (I and II) ✓	RAPRA Technology Ltd	Chemical Industries Association
Glass ✓	Glass Manufacturers Federation	Glass Manufacturers Federation
Aluminium ✓	BNF Metals Technology Centre	British Aluminium Federation
Cement ✓	Rugby Portland Cement Co	Cement Makers Federation
Non-Ferrous Metals ✓	BNF Metals Technology Centre	British Non-Ferrous Metals Federation
Retail Trades ✓	NIFES Tesco Stores Plc	The Retail Consortium Institute of Grocery Distributors
? Frozen Foods ✓	British Food Manufacturing Industries Research Association	British Frozen Food Federation Food and Drink Federation National Cold Storage Federation UK Association Frozen Food Production
Distilleries ✓	British Food Manufacturing Industries Research Association	Malt Distillers Association of Scotland Scotch Whisky Association Vodka & Gin Rectifiers and Distillery Association
? Local Authorities ✓	Local Authorities Management Services and Computer Committee	Local Authorities Management Services and Computer Committee
Water ✓	Messrs Clifford, Talbot & Jaehme	Water Research Council Water Authorities Association Water Companies Association
Buses and Coaches ✓	Bus & Coach Council	Bus and Coach Council

Table 2/1 Energy Efficiency Office M & T programme at end of 1986

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2. A strategy for improving energy management in UK Industry and Commerce – the Energy Efficiency Office Programme

In 1980, the Department of Energy initiated its Monitoring and Targeting programme to stimulate the development of effective energy management systems. The programme was designed to show how energy use could be controlled and how real improvements in the efficiency of energy use could be achieved.

The programme was based on the development of monitoring and targeting as a system of energy management which would help overcome the barriers to improvements in energy efficiency. Market forces and the need to reduce costs should then work to influence management decisions and lead to the better economic use of energy resources.

Making better use of energy is essentially a matter of good resource management: the right economic balance has to be found between the use of energy and other resources – including capital – within recognised and accepted constraints which may, for example, be set by market conditions, or by social or environmental requirements. Changes in tariffs and relative fuel costs will need to be considered and, in manufacturing industry, when sales are production limited or when a special requirement has to be met, an increased use of energy may be fully justified.

Tight cost control over energy use can help in reducing waste and in maintaining an established level of energy efficiency. Cost controls by themselves do not however provide the information which is needed to show (a) whether energy is being used efficiently and (b) what measures could be taken to improve the efficiency of energy use.

To establish control over energy use it is necessary to have information on how much energy is being used, where it is being used, and the results which are being achieved. With this information and corresponding information on energy costs, energy use can be controlled in the same way as the use of other resources.

Once control over the use of energy has been established by monitoring, targets can be set for improvements in the efficiency of energy use. This is the essence of the Monitoring and Targeting approach to energy management.

A properly designed Monitoring and Targeting system of energy management provides.

- tight control over energy use and reductions in energy costs,

- methods for optimising energy efficiency under varying conditions,
- the information needed to make further improvements in both operating practices and the efficiency of energy-using equipment,
- a strategy for achieving improvements through target-setting, and
- a method for assessing improvements and maintaining efficiency at the new level.

The Energy Efficiency Office M & T programme consists of two parts:-

1. The development and demonstration of appropriate M & T energy management systems for selected energy-consuming sectors of the economy and
2. The marketing and promotion of these energy management systems within each sector.

In the first part of the programme, the monitoring and targeting system for the sector is developed, with the cooperation of representative companies or organizations, under an Energy Efficiency Office contract placed, whenever possible, with the Trade or Research Association for the sector. For assistance in the development work, the Trade or Research Association may seek the aid of energy management consultants or an organization with previous experience in the operation of energy management systems.

This approach ensures the development of practical systems which have been tested in a working environment and shown to be effective. Management and staff in the companies and organizations involved, take part in developing and setting up systems which are appropriate to the requirements of their energy-using sector, and then operate these systems under practical conditions to cut down on energy wastage, optimise working practices, and improve operational efficiency.

Monitoring and targeting procedures were initially developed and tested in pilot studies in two manufacturing industries:- paper and board, and textile finishing. Appropriate M & T systems were successfully developed for these sectors with significant benefits (3 to 23% reductions in annual energy bills) to the firms taking part.

Following the success of these pilot studies, the Energy Efficiency Office programme was extended to cover some forty sectors. A list of the studies in progress at the end of 1986 is given in Table 2/1.

Details of the energy cost reductions achieved by the firms taking part are given in Section 5.

The work of developing an appropriate M & T system has followed a similar course in each of the sectors. Suitable methods for monitoring energy use and setting targets are developed and thoroughly tested in representative companies or organizations. A description of the complete M & T system with details of the recommended procedures is then set out in a manual which can be used as a guide by other firms or organizations in the sector.

In the second part of the Energy Efficiency Office programme, the wider use of M & T is being encouraged by promotional campaigns with the active involvement of Trade and Research Associations. By the end of 1985, forty sites in the paper and board sector, sixty in textile finishing, and ten in the private steel industry were implementing the monitoring and targeting systems developed for these manufacturing sectors. By the end of 1988 the number of UK sites implementing M & T will have surpassed 500.

3. Principles of M & T

Monitoring and Targeting is a disciplined approach to energy management which ensures that energy resources are used to the maximum economic advantage. With a properly organized M & T system, managers at all levels within an organization will seek to achieve improvements in the cost-effective use of energy.

Monitoring and Targeting has two principal facets:-

1. The on-going control of energy use.
2. Planned improvements in the efficiency of energy use.

M & T systems may vary in detail but there are some important general principles which need to be followed.

Control of energy use

The responsibility for controlling energy use should be firmly tied to (a) responsibility for the control of related resources and (b) accountability for achieving objectives. Thus the areas for the managerial control of energy will generally correspond with those for the use of other resources. For example, in manufacturing industry, responsibility for the control of energy costs will rest with line managers along with that for labour, materials and other costs.

An energy accountable centre (EAC) will usually correspond with an existing cost control or profit centre and may, for example, be based on a single building, the whole of a small manufacturing site, a production line, a central boiler house, or some other specific part of a manufacturing process. Key information on energy use can then be built into operating statements along with costs and other information on performance such as material utilisation, levels of output, losses, and yields.

The amount of energy used by an EAC in a given period is calculated from the measured quantities of fuel and electricity, and expressed in gigajoules (GJ), kilowatt hours (kWh) or therms. An appropriate index is chosen as a measure of the energy used in relation to the results achieved. When energy is being used to heat a building, this may be the annual energy use per unit floor area; in manufacturing industry, it is often energy used per tonne of product, but some other measure of production output can be used. The amount of energy expended in achieving a result corresponding to the selected unit is the specific energy requirement (SER).

For each EAC, agreed standards of performance for energy use are set up. The methods used to set a standard – the expected energy requirement under given conditions – are

treated fully in Annexe A. When energy is used mainly for heating buildings, the standards usually take account of seasonal variations in the weather. Similarly, in manufacturing industry, allowances are made for variations in the level of production, changes in the product mix, or other factors which directly affect performance. The standards serve as yard-sticks for controlling energy use and assessing performance. They can also be used for comparing the performance of one EAC with another.

Regular comparisons of the actual performance of an EAC against the agreed standards are held, at intervals and at management levels appropriate to the costs involved. When energy consumption is high or the organization is large, reviews will be needed at daily, weekly or monthly intervals as the management levels are ascended. The reason for any significant deviation, or variance*, of energy use from the standard is sought and if the deviation is unfavourable corrective action is taken.

With computer-based energy-management systems the underlying principles for maintaining control of energy use are similar. The operation of the system must be examined regularly to ensure that standards are being maintained. In the advanced systems developed for use in the chemical industry (3, 4), the energy efficiency is compared continuously with the expected or standard value. To obtain full value from a system of this type, information on performance needs to be made continuously available to plant operators and managers so that they can take immediate action to control energy use and improve performance.

* The term "variance" is used here in the accounting sense and represents the deviation of the actual result from the expected, budgeted or standard result.

Improvement of the efficiency of energy use

When standards for current performance have been defined and accepted in practice, targets are set for improvements in the efficiency of energy use. These may be fixed arbitrarily – the "top-down" approach – and the target could, for example, be a 5% improvement in efficiency within twelve months. It is however usually better to use the "bottom-up" approach and set realistic targets based on planned improvements in efficiency. The opportunities for improvement can be identified through an energy audit. This provides the necessary information on energy use and energy losses, the energy-saving measures can be identified, and the potential cost savings estimated.

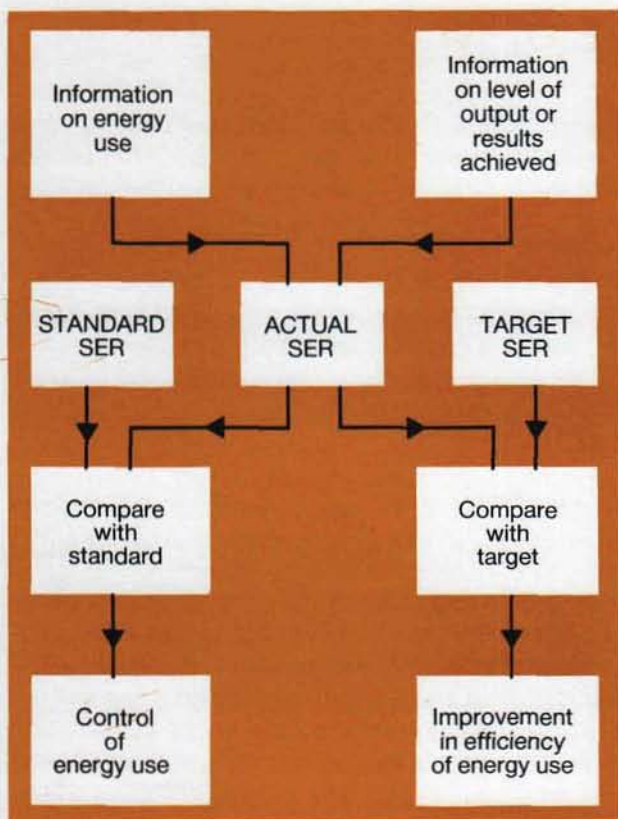


Fig. 3/1 Use of standards and targets to control and improve efficiency of energy use

The improvements may involve changes in operating practices, modifications of existing plant or buildings, or capital investment in new more energy-efficient processes and equipment. Cost-effective measures are implemented when financial and other constraints permit, and a target is set for the expected improvement in efficiency of energy use. Progress towards the target is monitored and when it has been reached and performance has been sustained at the new level, the target can

become the new standard. The cost savings achieved and the return on investment can then be calculated from the improvement in the efficiency of energy use.

The way in which standards and targets are used to control and improve the efficiency of energy use is shown schematically in Figure 3/1. An example of the use of M & T in the private sector of the steel industry for controlling and improving the efficiency of energy use in a billet reheating furnace is shown in Figure 3/2. The standard SER, which depends on throughput, is represented by the upper curve and was derived from the performance of the furnace during 1983. Improvements in operating practice during 1984 gave the results shown; nearly all of these fell below the target SER represented by the lower curve (which corresponded to a 5% reduction in the standard value).

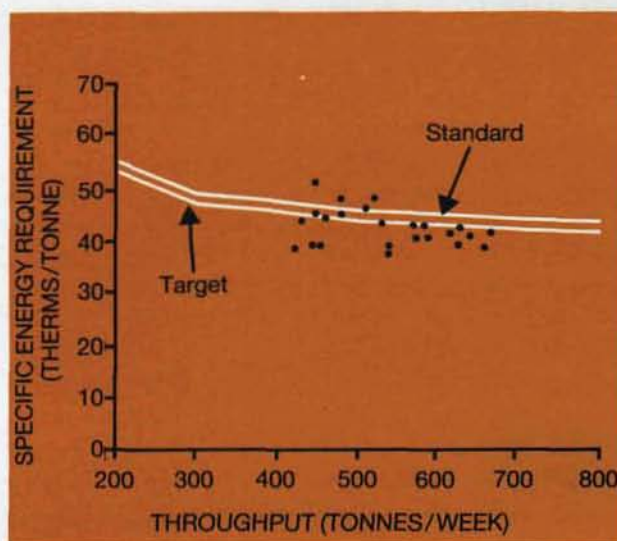
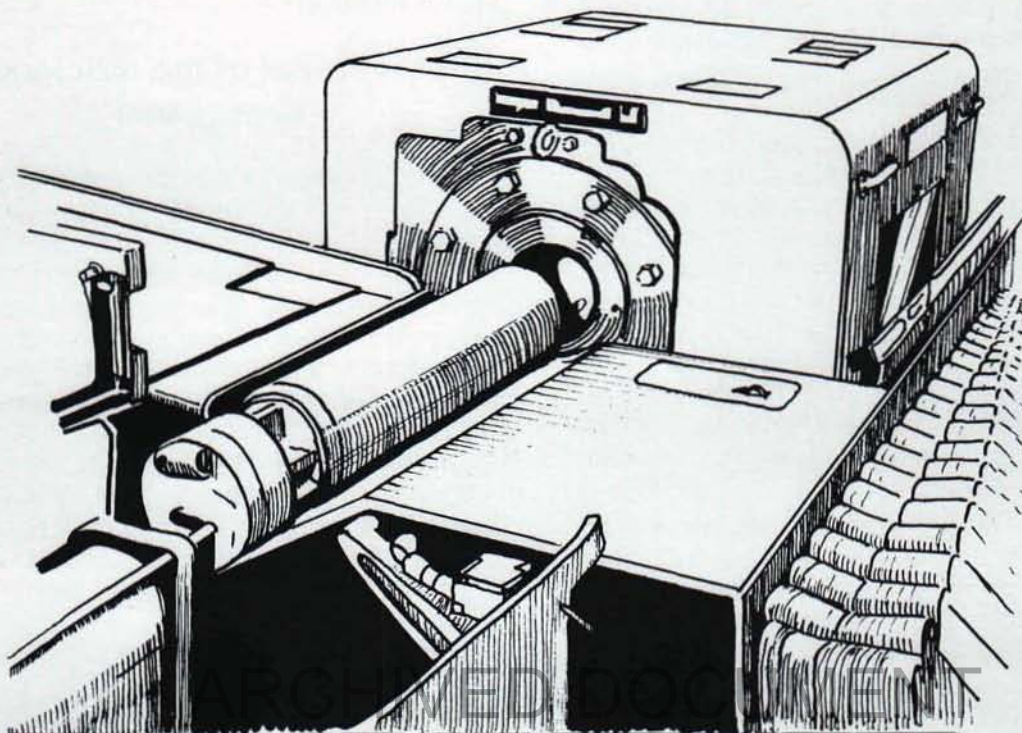


Fig. 3/2 Standard and target performances for a billet reheating furnace



A billet reheating furnace

4. Elements of an M & T System

4.1 Management and organization

The way in which a monitoring and targeting system is set up will depend on the size of the organization, the existing management structure, and the annual energy bill. The management objectives will however remain the same:-

1. To improve efficiency in the control of energy use by continuously measuring performance against reference standards. This provides the basis for a management-by-exception approach in which the reasons for deviations from the standard are investigated and corrective action taken whenever necessary.
2. To further increase the efficiency of energy use by setting realistic targets. These provide the motivation for improvement.

To achieve these objectives, top management commitment is essential and the M & T system needs to be incorporated in the existing management structure in such a way that energy use is properly controlled at all levels in the organization.

The time and effort which would be justified in setting up and running an M & T system can be judged by considering the value of a 5% saving on the annual energy bill, for example, £7,500 on £150,000 per annum.

In a small organization with an annual energy bill less than £150,000 the system will have to be kept as simple as possible. The effort required should be reduced to a minimum and, whenever practicable, accommodated within existing work loads. Early success in achieving improved performance can stimulate further action; with an over-elaborate or cumbersome system, momentum and interest can be lost. The responsibility for M & T should rest with a senior member of staff who has the necessary authority to ensure the system operates smoothly and effectively. Monthly reports on energy use and quarterly meetings of a small management group will probably be appropriate. With larger organizations, an Energy Committee or Working Party can be set up to review and compare progress by different departments in improving performance. This is recommended in the scheme developed for use by Local Authorities.

In manufacturing industry, and especially in the process industries where rates of energy use may be very high, close coordination with business management will be essential. To achieve this coordination at the larger manufacturing sites, an Energy Executive will be needed.

This may, for example, include senior managers,

the accountant and the chief engineer. The chairman should be a director or senior member of staff with sufficient authority to ensure that all necessary resources are made available and any necessary action is taken. The Energy Executive will be responsible to the Managing Director for

- (a) developing the energy efficiency policy,
- (b) managing the M & T system,
- (c) agreeing and reviewing standards and targets,
- (d) examining energy cost-saving schemes and
- (e) ensuring projects are implemented.

In general, most management structures in manufacturing industry will be based on three levels of authority with corresponding responsibilities for the efficiency of energy use (5) :-

Level 1. Senior Management: with responsibility for the efficiency with which energy is used in the organization as a whole, in relation to other resources, and in the production of particular products.

Level 2. Middle Management: with similar responsibilities for the efficiency of energy use in relation to specific areas of the manufacturing process or divisions of the organization.

Level 3. Process Operators, Foremen and Supervisors: with responsibility for maintaining control over the efficiency of energy use in a particular item of plant or part of a process.

At all three levels, those responsible for controlling and improving the efficiency of energy use will need regular reports on energy use in relation to standards and targets. Providing these reports, analysing the energy data, developing standards of performance, and deriving the information needed for setting targets will be the task of an Energy Coordinator responsible to the Energy Executive. His duties may also include responsibility for the installation and operation of metering systems and the training of staff responsible for the collection and analysis of energy data.

Energy management structures of this type are being set up in many of the energy-intensive manufacturing industries. A typical structure for monitoring and targeting in the process industries is shown in Figure 4.1/1. Responsibilities at the different management levels are summarised in Figure 4.1/2. Appropriate information on performance in relation to standards and targets will be needed at all management levels. Methods of reporting are described in Section 4.5.

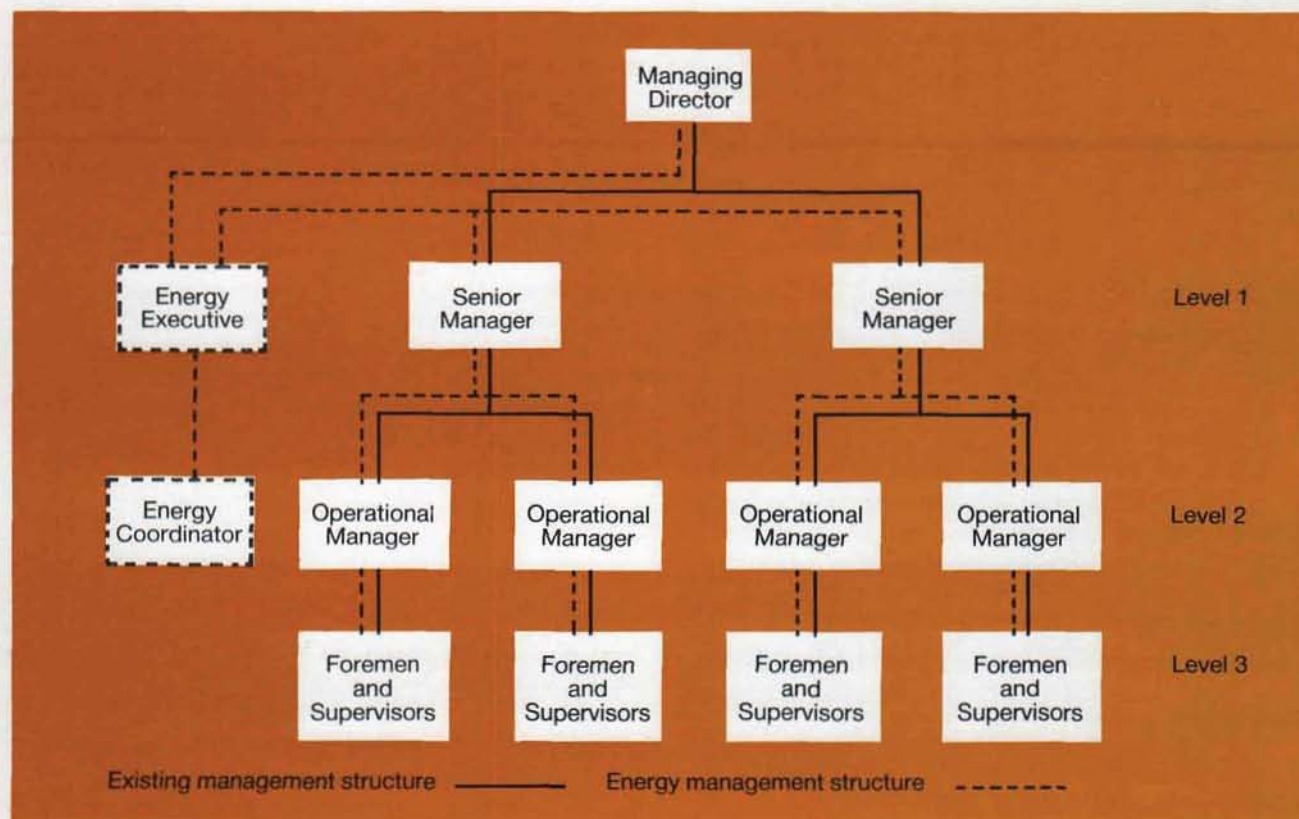


Fig. 4.1/1 M & T in the process industries – representative energy management structure

Setting up an M & T system usually involves the following steps:-

1. An energy audit and survey
2. The identification of energy accountable centres
3. The development of monitoring procedures
4. The definition of standards of performance
5. The development of procedures for the analysis of data and reporting performance
6. The definition of targets for improvements in performance.

These stages do not have to be taken in a strict sequence. For example, some work on the development of procedures for the analysis of data will be needed before standards can be set and the standards themselves will probably need to be refined as the system becomes established.

Experience has shown that it is often better to make a start with a simple system and achieve an early success. An unnecessarily complex system should be avoided and it may be wise to seek advice from a consultant with experience in setting up monitoring and targetting systems.

Management Level	Responsibilities
Managing director or director with responsibility for energy management	Chairs Energy Executive and is responsible for effective implementation of M & T and efficient use of energy in organization as a whole
Energy Executive	Development of energy efficiency policy, managing M & T system, agreeing and reviewing standards and targets, examining schemes for improvement of energy efficiency, and ensuring projects are implemented
Energy Coordinator	Operation of M & T system, analysis of energy data, derivation of information for standards and targets, and staff training
Senior Management (Level 1) Middle Management (Level 2)	Responsibility and accountability for improving performance by monitoring efficiency of energy use against standards and reviewing progress towards targets
Process Operators, Foremen and Supervisors (Level 3)	Continuing responsibility for ensuring plant is operated to standards of performance which are agreed and understood

Fig. 4.1/2 M & T in the process industries – energy management responsibilities

4.2 Energy audit and site survey

Before setting up an M & T system, an energy audit and site survey is recommended (6). These provide the essential information required to establish the technical basis and organizational structure of the M & T system. The main aims of the energy audit will be:-

1. To obtain information on energy consumption and energy costs over the preceding 1 – 2 years, broken down according to the energy source (oil, natural gas, coal, or electricity) and, where appropriate, corresponding information on the results achieved.
2. To estimate how much energy is used in different applications, e.g., in space heating or in manufacturing processes, and to find out what factors influence the rate of energy consumption.
3. To identify (i) the opportunities for energy saving and (ii) the measures which could be taken to improve energy efficiency.
4. To estimate the cost of implementing these measures and the potential savings in energy costs.

The main objective of the survey will be to find out the best way of incorporating M & T into the existing management system. The management structure will have to be examined and it will usually be necessary

- (a) to find out how fuels and electricity are distributed to different parts of the site; to prepare flow diagrams showing service runs and the position of existing meters and, in the case of manufacturing industry, corresponding diagrams for material flows;
- (b) to examine the existing procedures for energy monitoring and control; and to identify the channels used for information on energy use and, in the case of manufacturing industry, on output and the use of materials;
- (c) to identify the energy accountable centres and decide where additional metering will be required;
- (d) to establish the organizational basis for the M & T system; to assess the time and effort needed to operate the system including the training requirements; and to estimate the operating costs for comparison with the potential cost savings.

These actions do not have to be carried out in a strict sequence and a preliminary estimate of the potential savings will provide a guide to the costs which can be justified in setting up and running the system.

Unless the information is already available, the first step in carrying out the energy audit will usually

be to work out the annual energy consumption of the site as a whole. To obtain the total energy consumption, the amounts of energy provided by the fuels and electricity purchased have to be expressed in a common unit. This can be the therm or the kilowatt hour but, with the general trend towards the use of the International System of Units (SI), a multiple of the joule is preferable. The gigajoule (1GJ = 10^9 joules) or the megajoule (1MJ = 10^6 joules) is usually convenient. Further information on SI units is given in Appendix I and factors for the conversion of the commonly used energy units into the equivalent values in SI units are given in Appendix II.

Information on the amount of each fuel purchased during the last financial year and its cost should be available from invoices; corrections for changes in stock levels can then be made, if necessary, to obtain the amounts used. The corresponding quantities of energy can be calculated using the gross calorific values given in Appendix III, but the actual values for the fuels supplied should be used whenever possible.

A typical breakdown of the annual energy consumption at a factory with an annual fuel and electricity bill of around £150,000 is shown in Table 4.2/1. A similar breakdown for a steel plant with fuel and electricity costs of £1.2M per annum is given in Table 4.2/2. The fuel and electricity costs given in these illustrative tables are based on the average prices paid in 1984 by about 900 large consumers in manufacturing industry. In carrying out the audit, the actual prices should be used. The cost breakdown can provide a useful guide to where the greatest financial savings are likely to be made. For large sites a Pareto diagram may be helpful. This may show, for example, the number of buildings for which the annual energy consumption is less than a given value.

At some sites where, for example, natural gas or fuel oil is used for space heating and electricity is used mainly for lighting, the amounts of energy used annually in different applications may be easily distinguished and directly calculated from the quantities of fuel and electricity used. At other sites where, for example, fuel oil is used both for space heating and to provide domestic hot water, the amounts used for each purpose may be estimated in the way described in Annexe A.

For a site in manufacturing industry, the energy audit should provide information on energy usage in all major applications. If separate meters have not been installed for the main areas of production, meters can be hired or consultants called in to carry out a metered energy efficiency survey. There will however be some sites, e.g. in the textile finishing industry, where a wide range of processes are carried out on a variety of materials. At these sites, a detailed breakdown of energy use will be impracticable, and monitoring will have to be

Energy Source	Quantity of fuel or electricity used in original units	Price per unit of supply £	Fuel and electricity costs £	%	Energy consumption		Energy cost £/GJ
					GJ	%	
Coal	490 tonnes	49.6	24304	16.1	14210	29.6	1.71
Fuel Oil	510,000 litres	0.147	74970	49.6	21420	44.6	3.50
Natural Gas	82,000 therms	0.263	21566	14.3	8651	18.0	2.49
Electricity	1,050,000 kWh	0.0289	30345	20.1	3780	7.9	8.03
Total			151,185		48061		

Table 4.2/1 Annual energy consumption at a manufacturing site

Energy Source	Quantity of fuel or electricity used in original units	Energy consumption		Fuel and electricity costs	
		GJ	%	£	%
Electricity	10,000 MWh	36,000	8.3	289,000	27.5
Fuel Oil	3500 gallons	668	0.2	2,340	0.2
Natural Gas	1,000,000 therms	105,500	24.4	262,700	25.0
Coal	10,000 tonnes	290,000	67.1	495,900	47.2
Total		432,168		1,049,940	

Table 4.2/2 Annual energy consumption at a steel plant

Area of application	Annual energy consumption	
	GJ	%
Manufacturing process	12,200	46.9
Space heating	6,000	23.1
Lighting	1,300	5.0
Boiler plant and other losses	6,500	25.0
Total	26,000	

Table 4.2/3 Breakdown of natural gas consumption at an integrated steel plant

Area of application	Annual energy consumption	
	GJ	%
Steel plant	110,000	22
Steel plant offices	3,000	<1
Rod mill	320,000	64
Rod mill offices	2,000	<1
Main offices	5,000	1
Canteen	10,000	2
Engineering	50,000	10
Total	500,000	

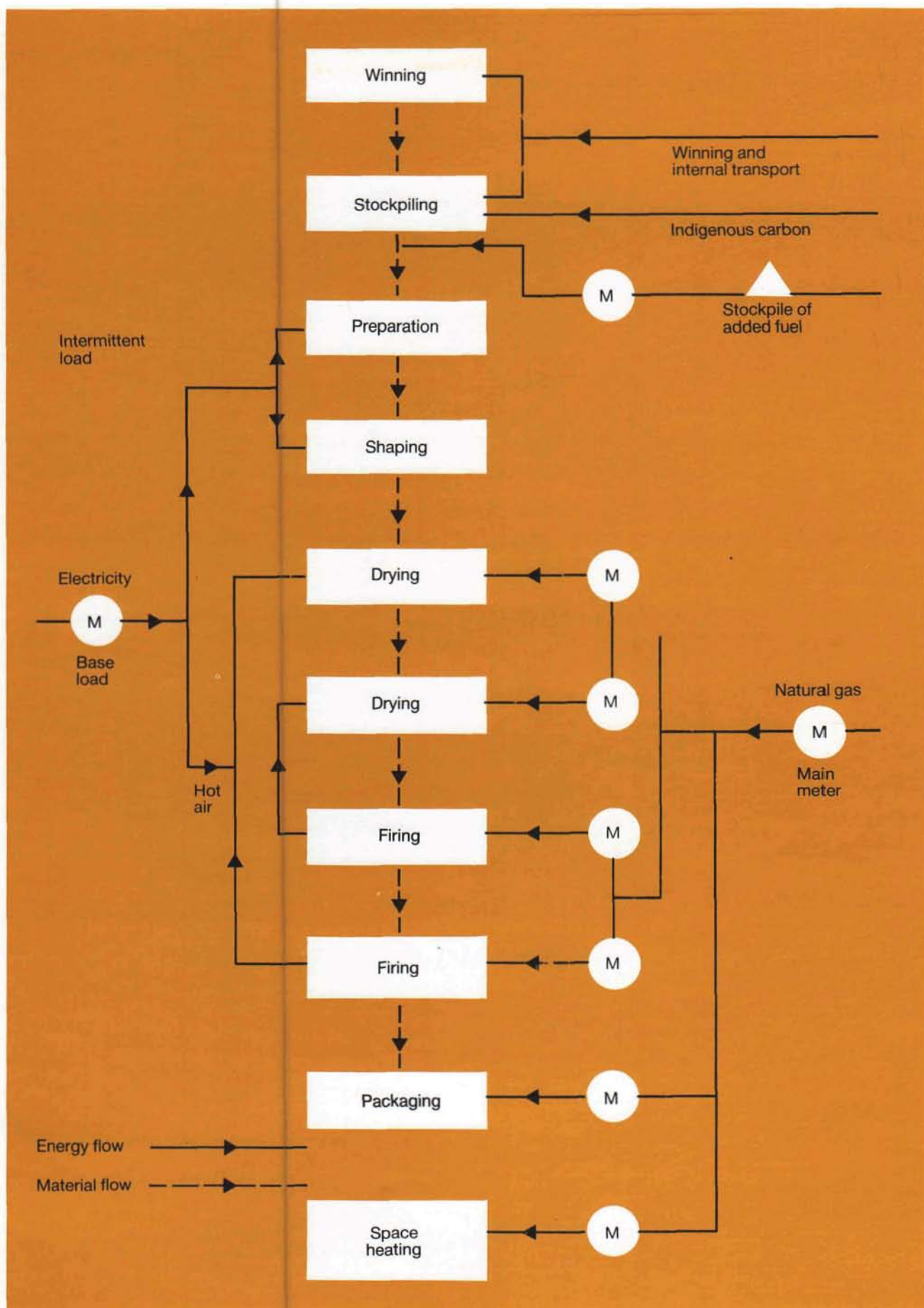
Table 4.2/4 Breakdown of natural gas consumption at an integrated steel plant

based on information derived from the quantities of fuel and electricity purchased. A typical breakdown of annual energy usage at a small factory is shown in Table 4.2/3 and a similar breakdown for natural gas consumption at an integrated steel plant is given in Table 4.2/4 (7).

A preliminary assessment of the effect of seasonal variations in temperature and other factors on energy consumption can be made by first plotting available data for the quantities of fuel and electricity used each week or month during the previous 12-18 months against time, and then plotting the corresponding values for production output and other factors in the way described in Annexe A. The amount of information collected and the degree of analysis needed will depend on the size of the site and, in manufacturing industry, on the complexity of the processes.

The energy audit should also include an investigation of the opportunities for increasing the efficiency of energy use. At most sites, energy cost savings of 5 – 10% should be possible with little capital investment. These opportunities can be identified using published check lists (8). The measures which could be taken to improve the efficiency of energy use should be specified in the audit which should also include estimates of the capital expenditure required and the potential cost savings.

The two most important objectives of the site survey will be to identify the EACs and to develop the basis for an M & T system which is integrated with the existing management structure. The first step will usually be to find out how fuels, electricity and steam are distributed to different parts of the site and the location of existing meters. At a site where energy is used mainly for space heating, the EAC may be a single building or a group of



buildings. With premises which consist of a large number of buildings, a start can be made with a few representative buildings, and the system can then be expanded when it has been shown to be cost-effective (9)

At a site in manufacturing industry, the number and location of the EACs will depend on the annual energy consumption and the nature of the manufacturing processes. At a small factory, the energy consumption of the whole site may be monitored through a single EAC. At larger sites, and especially in the process industries, the EACs will correspond with the main stages or areas of production, so that line management is directly accountable for the efficient use of energy, and energy use can be directly related to throughput at each stage in the manufacturing process.

An EAC should, whenever possible, be associated with an existing cost centre (or group of cost centres) and, in deciding on the location of an EAC, it is also necessary to consider

- (i) whether the estimated energy consumption for the EAC and the potential cost savings would justify the cost of metering and the effort involved in monitoring, and
- (ii) whether the energy used can be satisfactorily related to throughput or the results achieved so that reliable and practical standards of performance can be established for the EAC.

If there are too many EACs it may be difficult to cope with the information produced; if there are too few, important energy-using processes may not be

satisfactorily monitored. Diagrams showing the flow of materials through a manufacturing process, the lines of distribution for fuels and electricity, and the position of existing meters can be helpful in deciding on the location of EACs. The process flow diagram for a manufacturing site in the clay brick industry (10) shown in Figure 4.2/1, provides an example.

When the use of energy on the site has been assessed and the location of the EACs has been decided, an information flow diagram can be developed which takes into account the existing information channels and leads to an M & T system which is incorporated in the existing management structure. Control over energy use will then be established alongside control over other resources. A typical information flow diagram for an M & T system in manufacturing industry is shown in Figure 4.2/2. A close hold over energy use at plant level is maintained on a day-to-day basis through the central control loop shown in the diagram. Deviations from the standard SER are reported directly to those immediately responsible for plant operation so that corrective action is taken, whenever necessary and as soon as possible. Progress towards targets (which may have to be adjusted to allow for the effects of changes in manufacturing conditions) is monitored by operational management. Key results, which may be derived from more than one EAC are reported to top management at weekly or monthly intervals. The overall performance is reviewed periodically by the Energy Executive.



Energy executive meeting

4.3 Measurement of energy consumption

To maintain control over the use of energy it has to be metered reasonably accurately. This usually involves measuring the rate of consumption of fuels and electricity but sometimes it will be necessary to measure the heat flow corresponding to the use of hot water, steam or other fluids.

Where the annual energy consumption is relatively low, as at a small manufacturing site, and gas is the only fuel, sufficient information may be provided by the main gas and electricity meters. At larger manufacturing sites, additional sub-metering will usually be necessary for all major energy-consuming areas. In principle, separate metering should be considered wherever the cost of an individual fuel or electricity exceeds say £10,000 per annum and the potential savings can be expected to recover the cost of metering within a reasonable time. In practice, it will usually be best to start by metering those areas which account for say 80% of the energy consumption. The remaining 20% can then be monitored as a whole and additional metering installed if it proves to be necessary.

For natural gas, propane and butane, positive displacement or turbine meters may be used. The former are more expensive but give accurate results over a wider flow range. The volumes measured should be corrected for temperature and pressure if these differ significantly from STP (60°F or 15.6°C and 30" Hg or 1.016 bar). The rate of fuel oil consumption can be measured with a liquid flow meter or, less accurately, with a calibrated oil-storage tank contents gauge.

Measuring coal consumption accurately over short periods is difficult. Calibrating the solid fuel feed system to a boiler appears to be unreliable, and measurements based on quantities of coal delivered and estimated stock levels will only be approximate. It will usually be best to meter the steam or hot water produced and monitor boiler efficiency separately. For metering steam directly, an orifice plate or pitot head with differential pressure meter and integrator is usually employed. Consideration should be given to the use of a variable orifice or vortex shedding type of steam meter where the flow range is large. For measuring steam output from a boiler plant, a less expensive alternative is a feed-water meter fitted to each boiler (Figure 4.3/1). The quantity of feed water supplied will correspond closely with the quantity of steam raised since losses on blowdown will be relatively small. A make-up water meter will also give a good indication of the use of live or untrapped steam. For measuring the use of hot water, integrating meters are available which give the heat flow from measurements of water flow and temperature.

Integrating meters with split-ring current transformers can be useful for preliminary measurements on low-voltage electricity supplies but a meter fitted directly in the line will usually be preferable as a permanent arrangement. Where an electrical load is essentially constant and relatively small, an hours-run meter can be used to measure electricity consumption.

When meters are read visually, mistakes will be less likely with the digital than the dial type. If the installation of a remote reading system is a possibility in the future, the purchase of meters with pulsed outputs should be considered.

Typical costs for likely sizes of meters range from less than £100 for a small fuel oil meter up to over £1,000 for a steam meter. The installation cost will vary with the type of fuel and depend on how much work has to be done in modifying existing cable runs or pipework. Where plant is in continuous operation, the meter should be installed with a bypass so that it can be removed without interrupting the process.

The pay-back time can be estimated to find out whether expenditure on meters is justified. For example, with energy costs of £40,000 per annum and energy cost savings of 5% per annum, the pay-back time for an investment of £3,000 in meters, on the basis of a simple calculation, would be 18 months. When major investment in meters is under consideration, the value of future savings can be discounted using the DCF technique. The pay-back time can then be calculated on this basis, or the real internal rate of return can be calculated to provide a comparison with the rate of return on other investment opportunities.

Regular reading of meters is essential; a reading taken at the wrong time can be seriously misleading. The intervals between readings should, when possible, be chosen so that they fit in with existing accounting procedures: for weekly readings, appropriate times might be the beginning or the end of the working week; for monthly readings, a fixed time on the last Friday in each month may be suitable. If individual meters are read visually, the meter reader should be provided with a log book or log sheet in which to enter the readings. A hand-held electronic data-logging device may be a convenient alternative.

The cost of gathering information can be reduced by installing a remote-reading system so that the readings from a number of meters are recorded at a single collection/storage station. A wide range of meters fitted with low or high frequency pulse generators for remote reading is now available. Each pulse can represent a fixed volume of fuel, a fixed amount of electricity or a fixed quantity of energy. For measuring heat flows, information from a flow meter fitted with a pulse generator can be combined with that from a temperature sensor.

When separate metering of the energy used in a number of different activities is impracticable, it may be possible to relate energy use in each activity to some indicator of energy consumption. Models can then be built up to represent total energy use by each EAC. This discrete model approach is described in Annexe A.

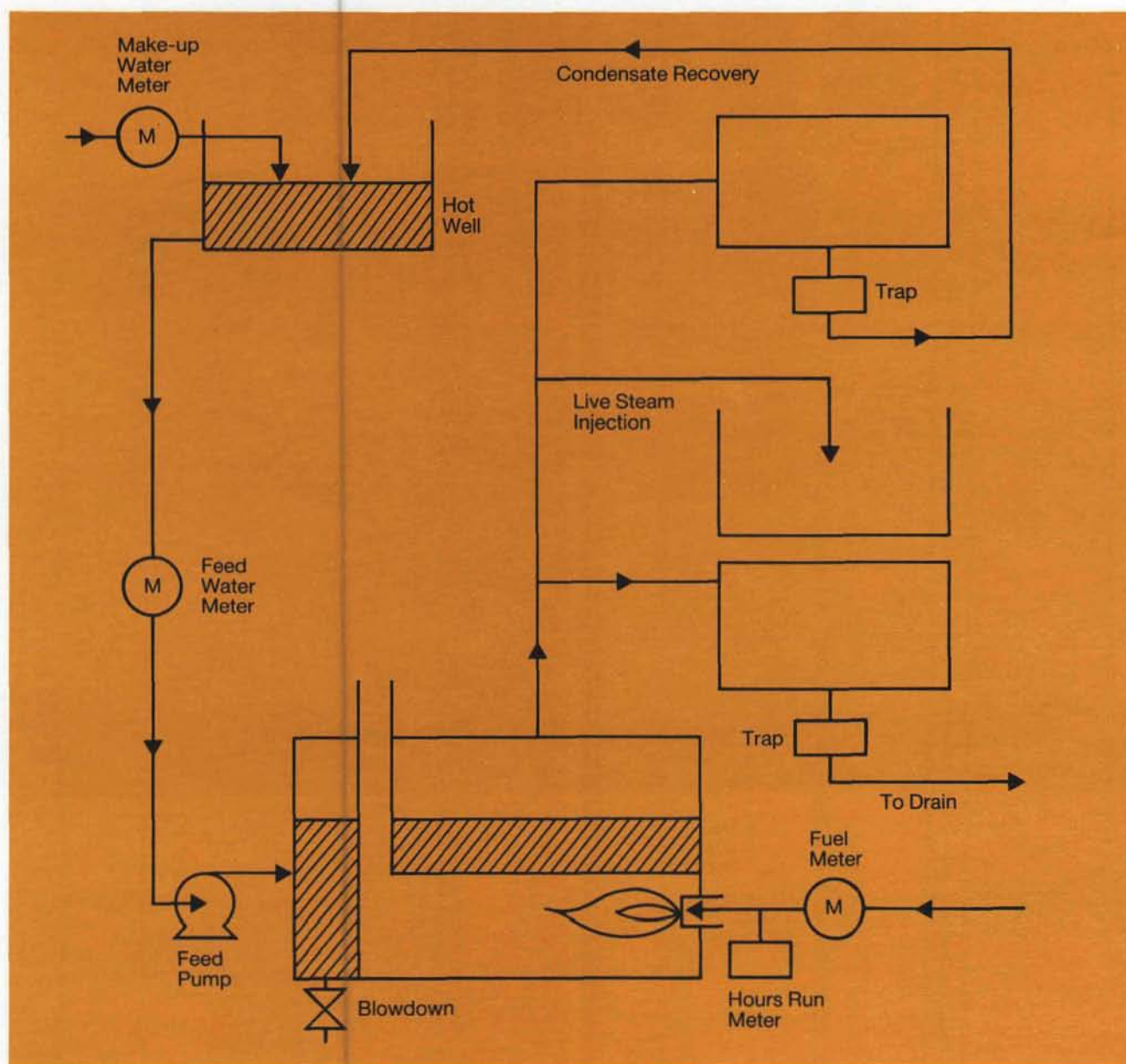
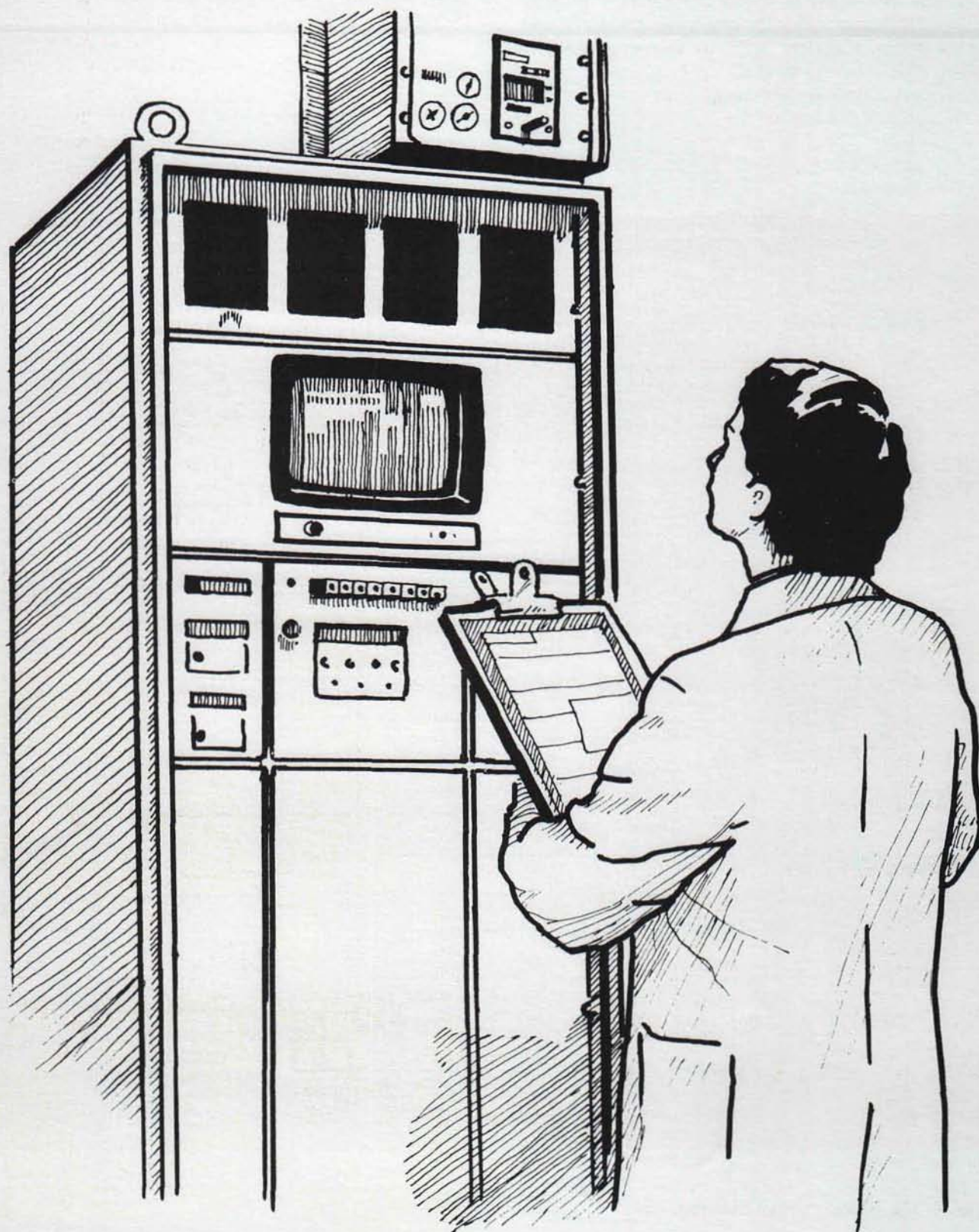


Fig. 4.3/1 Measurement of steam use



Meter reading at a single collection/storage station

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4.4 Specific energy requirement

To derive the specific energy requirement (SER), the results achieved through the expenditure of a given amount of energy should be expressed in terms of physical quantities. The SER will then be significant in real terms and will provide a measure of performance in the efficient use of energy which is independent of changes in economic values and prices. At the same time, by taking prices and values into account, it will be possible to use the SER to achieve the proper economic balance between the use of energy and other resources.

The measure chosen for the results achieved should be compatible with those used in existing accounting procedures and should lead to satisfactory correlations with energy use. Direct measures of output or results achieved should be used whenever possible but indicators of activity, e.g. standard hours, machine hours etc. may have to be employed.

In manufacturing industry, the output can be measured in terms of the number of items produced, tonnes or square metres of product, etc., but when there is a mixture of products a better correlation with energy consumption may be obtained if one measure of output is used rather than another. In processes where solid materials of varying form have to be heated, better correlations are usually obtained if weight or volume is used as a measure of output, rather than the number of items produced or the superficial area of the product. In the clay brick industry, for example, less energy is needed to manufacture a perforated brick than a solid brick of similar dimensions, and when bricks of differing weight are produced in the same plant, it is better to express the SER in GJ/tonnes rather than GJ/1,000 bricks (10). In the paper industry, where energy requirements will depend on the thickness of the paper, expressing the SER in GJ/tonne is better than using GJ/m².

Information on output will normally be available from production records, but additional monitoring may be required to ensure this information can be properly correlated with that on energy use. If the manufacturing processes are lengthy, or materials are stored at an intermediate stage in the process, care should be taken to make sure that energy used in the earlier stages of production is properly correlated with the final output. In continuous or semi-continuous processes, information on production can be collected using appropriate devices, e.g. flow meters for liquid and gaseous products, or event recorders for discrete units of output.

Where energy is used to provide heating or air-conditioning in buildings, the temperature inside the building usually has to be maintained at a required level, normally about 65°F (18.3°C). The energy required annually for space heating will

depend on the size and nature of the building, and on the rates at which heat is lost by ventilation (including draughts through doorways and other openings) and by thermal conduction through the building structure. For most buildings however, the energy requirements for space heating are found to show a good correlation with floor area, and the annual energy requirements are frequently expressed in terms of GJ/m²a, therms/m²a or kWh/m²a. With some buildings, volume corrections may be needed. Information on floor areas and building dimensions will normally be available from site plans. To obtain a reliable and generally applicable measure of space-heating efficiency, changes in weather conditions have to be taken into account. The methods used are described in Annexe A.

4.5 Monitoring — control of energy use

An effective monitoring system should be as simple and compact in structure as possible so that action is taken whenever necessary and without unjustified delay. The essential elements of the M & T control system are shown in Figure 4.5/1. The actual energy requirement is monitored and compared with the standard. The nature and

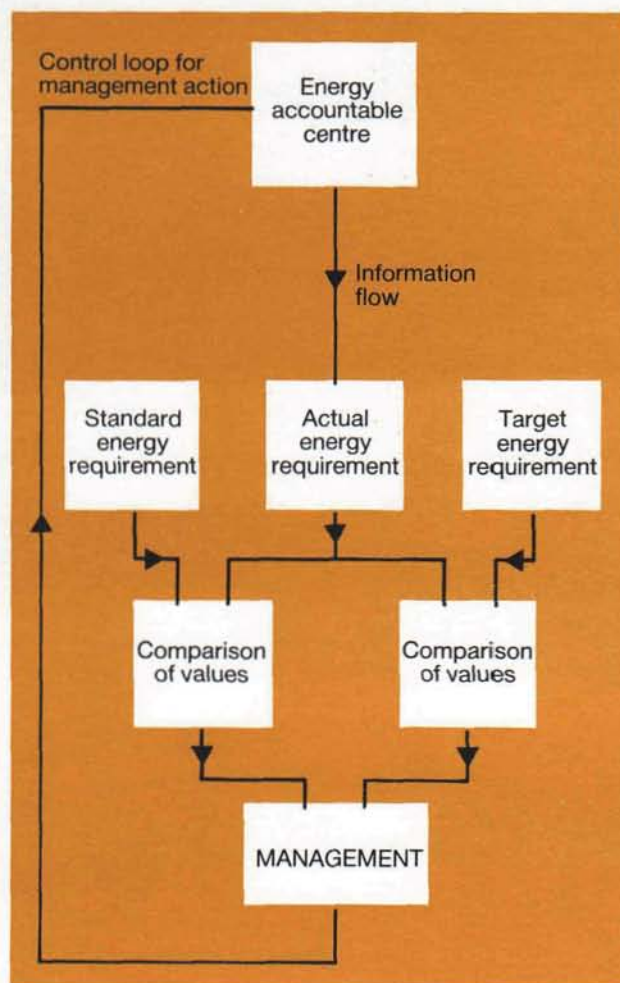


Fig. 4.5/1 Control system for energy monitoring

Where the main use of energy is for space heating, a form similar to that shown in Figure 4.5/2a can be used to record the weekly or monthly consumptions of each fuel and electricity. Metered consumptions can be compared with quantities invoiced and the unit cost for each fuel and electricity, in £/GJ or £/therm, can be calculated.

At the next stage, the monthly consumptions of each fuel and electricity can be entered in a form, similar to that shown in Figure 4.5/2b, for comparison with the values which would be expected under the prevailing weather conditions. The expected values will be given by the line of best-fit in the plot of monthly (or weekly) energy consumption against the corresponding degree-day values (Annexe A). If the actual value deviates significantly from the expected value, the reason should be sought and action should be taken to reduce any unnecessarily high energy consumption. Where there are several buildings, separately metered, a summary sheet can be prepared each month showing the actual and standard values for each building together with a suitable performance indicator, e.g., an energy consumption index in GJ/m²d where GJ is the energy consumption during the month, m² represents the total floor area of the building, and d is the number of degree days. These forms may need to be modified if corrections are required for base loads.

In manufacturing industry, a form similar to that proposed for M & T in the pottery industry (11) and shown in Figure 4.5/3 can be employed to record the weekly energy consumption and the corresponding throughput for each EAC. The actual SERs for the main processes are calculated and compared with the standard values as described in Annexe A.

Reporting to senior management is best done through key performance indicators such as the SER which relates energy use to output or the results achieved. When using a SER to judge performance, account should be taken of factors which may have prevented energy being used to the best effect. In manufacturing industry, for example, plant may have had to be run with a reduced throughput. This will generally result in a high SER and higher manufacturing costs. These effects need to be appreciated by upper management so that, when practicable, action can be taken and costs reduced. It may for example, be possible to reduce a SER by operating plant in short campaigns rather than continuously. The monitoring system itself should be reappraised periodically to make sure that attention is concentrated on items that matter and that effort is not wasted on gathering unnecessary information.

In the M & T system developed for use in the paper industry (5), the reporting system is designed to provide information on energy performance to the three basic authority levels:-

- Level 1 — Senior Management
- Level 2 — Middle Management
- Level 3 — Operational Management and Supervisors

At level 3, where information on energy use is monitored on a continuous or near-continuous basis and increasing use is being made of microprocessor based systems, operational management will be immediately responsible for the local control of energy use and ensuring performance is maintained in line with agreed standards.

WEEKLY ENERGY CONSUMPTION AND OUTPUT — SUMMARY SHEET					
W/E.....					
Energy accountable centre	Energy consumption GJ	Output t	Current SER GJ/t	Standard SER GJ/t	Deviation GJ/t
New mould making					
Making and shaping					
Handle casting					
Pre-kiln drier					
Once-firing					
Decorating drying					
Decorated firing					
Space heating					
Compressed air					

Fig. 4.5/3 Report form for energy monitoring in the pottery industry

At Level 2, the following reports for middle management are prepared on a weekly basis:

- Power house report
- Steam consumption report
- Electricity consumption report

In each of these reports, the energy actually used as steam or electricity per unit of production is compared with the agreed standard for each machine, and for each main product or production area. The forms also include a weekly energy audit: total energy supplied as steam or electricity is compared with the total used in the various parts of the process. The difference corresponds to energy consumption which cannot be accounted for, energy losses or errors in metering.

The reports at Level 1 are prepared at monthly intervals from the Level 2 reports. They provide senior management with a concise summary of overall performance in each of the main product areas. The energy efficiencies are expressed in (a) therms/gross tonne, (b) primary therms/gross tonne, and (c) therms/net tonne. The values actually achieved are compared with the agreed standards and the forms also include diagrams showing the trend in performance over the last twelve months (Figure 4.5/4). When calculating energy efficiency in primary therms/gross tonne, the quantities of bought-in electricity are multiplied by 3.0 to give the corresponding quantities of primary energy. The use of primary therms/gross tonne provides a reasonable basis for comparing

performance when there are differences in the proportion of bought-in electricity.

Although information in tabular form may be satisfactory as a record of performance, the visual presentation of results as a control chart (12) can show much more clearly whether energy use is properly under control. The control of energy use in clay brick manufacture provides a good example (9). Table 4.5/1 gives the weekly energy consumptions and throughputs for a particular kiln over a 12-week period together with the corresponding energy requirements. A control chart based on this data in which deviations from the standard values have been plotted in sequence against the week number is shown in Figure 4.5/5.

In general, the processes of this kind will show some inherent variability for reasons which may not be easily established. For control purposes however, warning lines can be drawn on the control chart above and below the mean value at levels determined by the estimated standard deviation (σ_e). If the lines are drawn at levels $\pm 1.96 \sigma_e$ above and below the mean value, then only 1 result in 40 would be expected to fall outside these bounds as a result of the inherent scatter in results. If two or three successive results fall close to or outside these set limits, it can be assumed there has been a real change in the energy requirement for the process. Figure 4.5/5 therefore shows with some degree of certainty that real energy savings are being achieved after week 60.

KILN THROUGHPUT AND ENERGY CONSUMPTION

Week no.	Kiln throughput (tonnes)	Measured energy requirement (therms)	Standard energy requirement (therms)	Deviation from standard (therms)	Cusum (therms)
55	942	29230	28505	+725	+725
56	1143	29080	30427	-1347	-622
57	950	28245	28582	-337	-959
58	1132	31994	30322	+1672	+713
59	994	28294	29002	-708	+5
60	994	26713	29002	-2289	-2284
61	1224	28275	31201	-2926	-5210
62	1327	28755	32186	-3431	-8641
63	1187	29396	30848	-1452	-10093
64	1215	29617	31115	-1498	-11591
65	1270	29342	31641	-2299	-13890
66	1278	29854	31718	-1864	-15754

Table 4.5/1 Monitoring kiln energy consumption in the clay brick industry

**THE BRITISH
PAPER AND BOARD INDUSTRY
FEDERATION**

ENERGY MANAGEMENT MONITORING AND TARGETING SYSTEM

Company & Mill Name

Month

	ENERGY EFFICIENCY REPORT	
--	---------------------------------	--

**EFFICIENCY IN THERMS PER GROSS
TONNE THIS MONTH:**

M & T
code

M & T
code

M & T
code

Mill/Machine:									
Product Group:									
Measure:	STD	ACT	VCE	STD	ACT	VCE	STD	ACT	VCE
1) Therms/Gross Tonne:									

**TREND LAST
12 MONTHS:**

Unfavourable %

favourable %

	20			
	10			
	STD			
	10			
	20			

OTHER DATA THIS MONTH:

Measure:	STD	ACT	VCE	STD	ACT	VCE	STD	ACT	VCE
Energy Cost per Saleable (net) Tonne: (£ per net tonne)									
Energy Cost: (£'000)									
Bought in Energy Used (therms '000):									
ENERGY EFFICIENCY									
2) Pr. Therms/Gr. Tonne:									
3) Therms/Net Tonne:									

CORRECTIONS FROM BUDGET THIS MONTH:

Seasonality:			
Product Mix:			
Volume:			
Broke:			

Fig. 4.5/4 Form for M & T reports to senior management in the paper and board industry

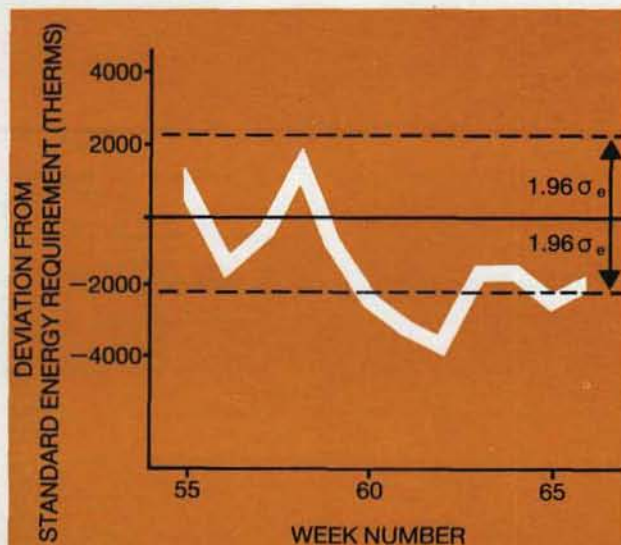


Fig. 4.5/5 Control chart for monitoring kiln energy consumption in the clay brick industry

A cusum chart provides an alternative method of graphical presentation (13) which has distinct advantages in M & T procedures. To construct a cusum chart, the cumulative sum of the deviations from the standard energy requirement for a given manufacturing throughput or operation is plotted against the serial number of the observation. (If the standard energy requirement is subtracted from the measured energy requirement, the deviation will be positive when the measured energy requirement is greater than the standard and negative when it is less). With this method of plotting, the average deviation of the measured value from the standard value, at the time of the observation, is represented by the local slope of the chart. When the measured value stays close to the standard value the path of the cusum lies roughly parallel to the sequence axis. If the local average energy requirement is less than the standard, the path of the cusum will slope downwards. An upward slope indicates a deterioration in performance.

Some care is necessary in choosing the scale for the cusum axis: too large a scale will give a saw-tooth appearance; too small a scale will damp out background variations but may obscure real changes in performance.

A cusum chart for the data given in Table 5.5/1 is shown in Figure 4.5/6 which also includes a slope guide or "cusum protractor" giving the deviations from the standard corresponding to different slopes. Initially, the path of the cusum is roughly parallel to the sequence axis showing the standard is being maintained, but after week 59 the cusum slopes downwards showing the measured energy consumption is running at a level more or less consistently below the standard. The average reduction in energy consumption given by the slope of the cusum is approximately 2,300 therms/week. The cumulative savings, given directly by the

chart, amount to nearly 16,000 therms by the end of week 66.

Most of the calculations required in setting up standards and in monitoring energy use can be carried out with an electronic calculator, but time and effort can be saved by the use of a microcomputer. Computer software is now available for M & T, and a general overview of the microcomputer-based system developed for use by Local Authorities is shown in Figure 4.5/7. Data input is by the keyboard from invoices or meter readings. Programmes are also available for transferring data from a building energy management system or from a mainframe computer to a microcomputer for analysis (14).

Time and effort spent in collecting data can also be saved by transmitting information from meters and sensors to a microcomputer for analysis. In a system developed for use in the steel industry (15), information from meters and sensors is fed as a digital or analogue output to one of a number of intelligence out-stations where the information is processed and stored ready for transmission to a central supervisor unit consisting of a dual-disc-drive microcomputer with printer and monitor.

At large sites in the energy-intensive industries where a range of products is manufactured, an overview of performance in the use of energy may be obtained from an analysis of information in the financial accounting system (16). For each product, a SER during a selected reference period can be calculated from the output and the quantity of energy used. The SER for the reference period can then serve as a standard for judging subsequent performance. From the information obtained for each product, and taking into account changes in the product mix, SERs can be calculated for each production area and for the site as a whole. In this way, actual and expected values for SERs can be monitored on a continuing basis.

In the process industries, where rates of energy consumption can be very high, plant performance may have to be optimised on the basis of economic factors which are changing on a day-to-day or even on an hourly basis (3). There may also be complex interactions between different plants on a large site: the product of one plant may be the feedstock of another and a decision to shut down one small plant could have repercussions over a whole site. With tight margins and restricted markets, up-to-the-minute information is required so that management can take immediate decisions on the action necessary to optimise performance to maximum economic advantage.

To achieve this result, a computer-based monitoring and targeting system has been developed in the chemical industry, which can resolve these complex issues on a real-time basis and present the necessary information in understandable terms (3,4). Data on process

variables – flow, pressure, temperature, etc. – is gathered and used to calculate the performance of specific items of equipment in the plant. Performance is then compared with standards, and the information on performance displayed, at plant level, in graphic, chart, trend, and specially designed “performance versus target” displays. In an ammonia plant, for example, the energy efficiency, in GJ/tonne ammonia exported, is continuously displayed and used in all daily reports. The performance data is compared with expected or standard values and if a deviation occurs, the display leads the operator to that part of the process which requires attention. Systems of this type have been integrated to provide economic performance control over individual plants, production areas, and manufacturing complexes from a single operation centre. Further applications for systems of this kind may be expected at larger manufacturing sites and at large and small sites in the energy-intensive industries.

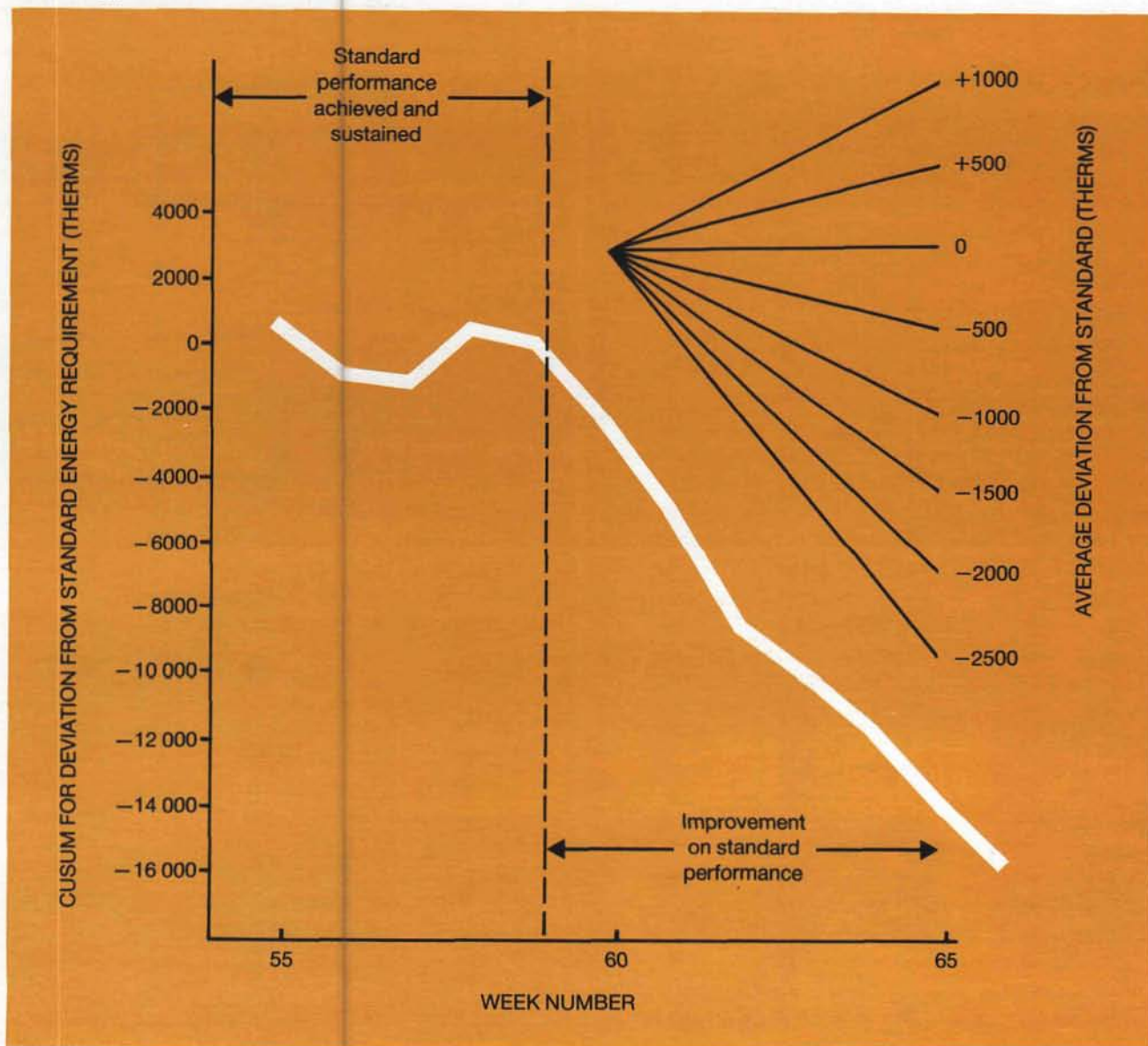


Fig. 4.5/6 Cusum chart for monitoring kiln energy consumption in the clay brick industry

MAIN MENU

1. Create/Amend site details
2. Average energy costs
3. Correction factors
4. Efficiency measures
5. Meter reading
6. Invoices
7. Linear regression
8. Performance index
9. Reports
10. Degree days
11. Update procedure
12. Quit system

Please choose option –

REPORTS MENU

1. Monitor and Target
2. Transaction Listing
3. Exceptions
4. Consumption Details
5. Site and Building Details
6. Cash Value Target Exceptions
7. Total Site Energy Ranking By Performance Index

Please choose option or ((ESC)) to Exit –

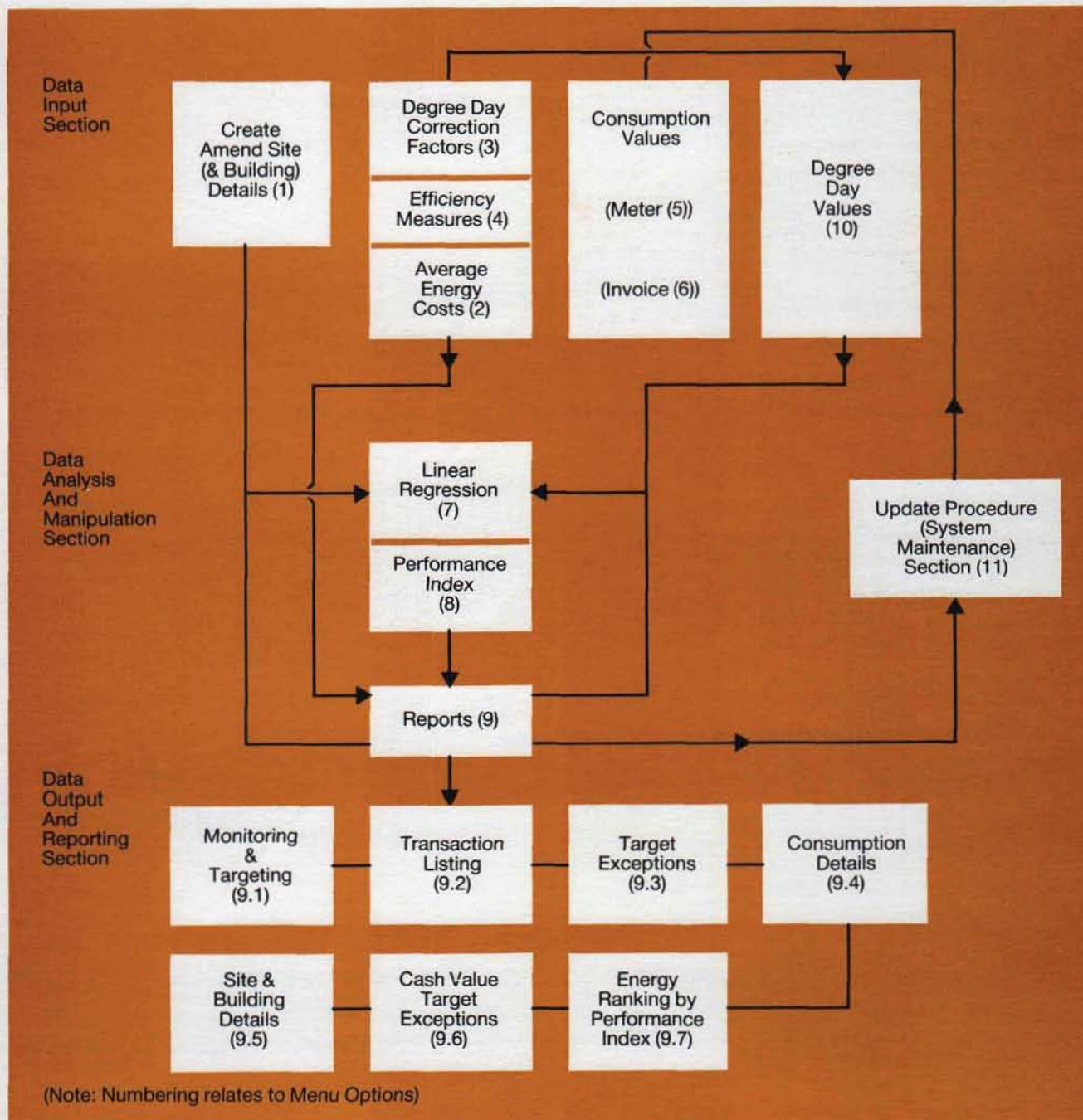
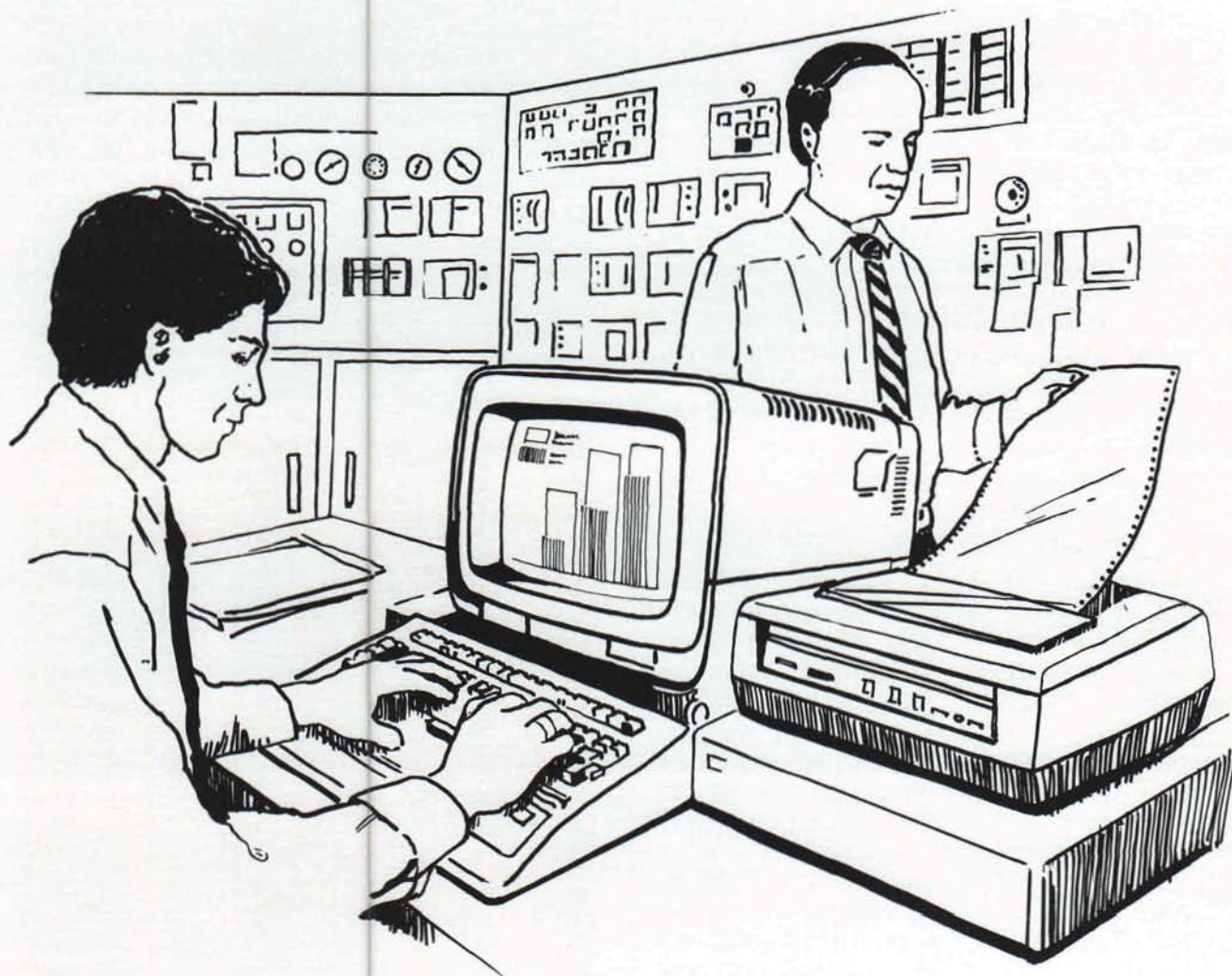


Fig. 4.5/7 Computer-based system for use by local authorities – operational flow diagram



"Auditor" in plant situation

4.6 Targeting — planned improvements in performance

When energy monitoring has been integrated into the management system and control over energy use has been established, targets should be set for further improvements in the efficiency of energy use.

Impossible or too-easily attainable targets should be avoided and purely arbitrary targets are undesirable; there should be evidence to show the improvements in performance are possible and how they can be achieved. A basis for setting targets will usually be provided by the opportunities identified through the energy audit and the information obtained from monitoring.

Targets may be set for individual EACs as well as for a site or organization as a whole. They will often be based on a general improvement in energy management, but may represent improvements in performance which would be expected and should be achieved as a result of specific measures such as the modification of existing plant, the installation of new equipment or the insulation of buildings.

A target should represent the achievement of a specified improvement in performance within a given period of time. The required improvement in performance may be

- (a) a reduction in energy costs or in the energy consumption or
- (b) the attainment of a lower SER.

A reduced SER will usually be the more satisfactory target since its achievement will clearly demonstrate that real progress has been made in improving the efficiency of energy use. The development of targets is described in Annexe B.

In judging performance against targets, allowances will usually have to be made for changes in the conditions under which energy is used. Variations in the weather from one year to the next may increase or decrease the energy requirement for heating buildings by 5 to 10%. In manufacturing industry, the effect of changes in the level of output or variations in the product mix may have to be taken into account and allowances made whenever necessary. Higher energy efficiencies can be achieved through improvements in the utilization of plant and resources, but they may be solely the result of higher levels of production with little if any real improvement in the actual efficiency of energy use. Lower energy efficiencies may be the result of unavoidable commercial factors which lead to plant being operated below capacity.

Reviews of performance and progress towards targets should be held at appropriate levels and suitable intervals. The successful achievement of the overall target for a company

or organization will normally be the responsibility of the chief executive and, in a large concern, heads of divisions or departments will have similar responsibilities.

Reviewing progress is especially important when capital has been invested to gain an improvement in performance, since it will provide information on the rate of return, demonstrate the value of the investment, and supply technical information for further improvements. In manufacturing industry, cusum charts plotted in the way described in Section 4.5 can be very useful in monitoring progress towards targets since they show the cumulative savings which have been made. The target is reached when the slope of the cusum corresponds to the target value. Alternatively, the cumulative sum of the differences between the measured values for the energy consumption and the target value can be plotted against the serial number of each observation. The use of a cusum plot to follow the approach to a target reduction in energy consumption is shown in Figure 4.6/1 which is based on the data in Table 4.5/1. The path of the cusum becomes horizontal when a target reduction of 2,300 therms/week in the kiln energy consumption is attained.

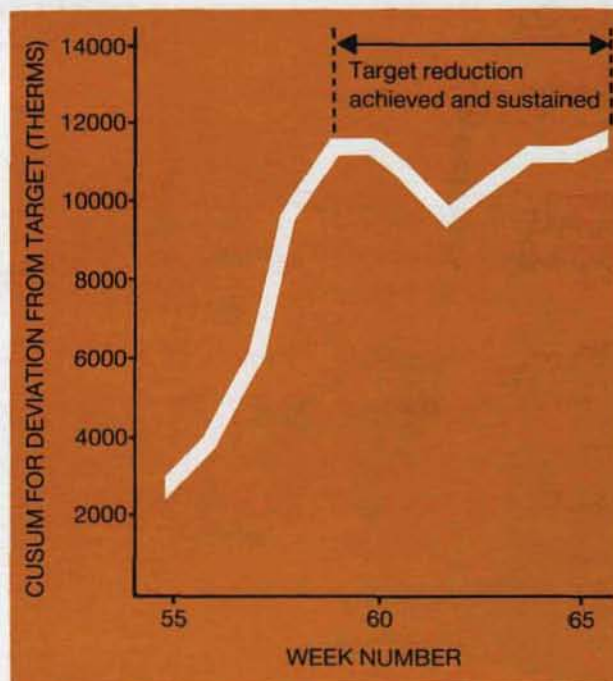


Fig. 4.6/1 Cusum chart for monitoring approach to target reduction of 2300 therms in kiln energy consumption

When assessing energy performance in the use of items of plant or equipment, it may be possible to compare the efficiencies achieved with published information or the manufacturer's specifications. Sometimes useful comparisons can also be made between the energy

efficiencies of similar items of plant or equipment at the same site or within the same organization.

When energy is used mainly for space heating, lighting, and the provision of hot water and other services in buildings, overall performance in the use of energy — in terms of annual energy consumption or annual energy costs per unit area — can be judged against published performance indicators (17, 18) for different types of buildings, e.g., factories and warehouses, offices, and hotels. By applying correction factors, the performance indicators can be adjusted to suit differences in the periods of occupation (e.g., a single shift 7-day week or continuous operation), the engineering services (e.g., air conditioning or mechanical ventilation) and the geographical location. More precise corrections for differences in climatic conditions and seasonal variations in outdoor temperatures can be made by making use of degree-day tables as described in Annexe A.

In the M & T system developed for use by Local Authorities (9), the actual monthly energy consumption for a building or group of buildings is normalised to give the energy consumption which would be expected on the basis of the 20-year average for the monthly degree-day value at the site. This is done by dividing the weather-related energy consumption by the monthly degree-day value and then multiplying by the 20-year average monthly degree-day value. The normalised annual energy consumption can then be related to the floor area to give an annual energy consumption index (expressed in GJ/m²a or kWh/m²a) which can be used to compare performance from one year to another. To compare performance at one site with another or with national data, the normalised annual energy indices can be adjusted in a similar way using the appropriate 20-year average degree-day values.

In manufacturing industry, comparisons of energy efficiencies at different sites within the same organization and between different companies manufacturing similar products can provide a competitive incentive and have led to significant improvements in performance. Some general information has been published on the energy efficiencies achieved in different sectors of manufacturing industry (Appendix V). In many sectors, the manufacturing activities differ considerably from one site to another and comparisons of overall energy efficiency can only be approximate. When the products and manufacturing processes are similar however, more rigorous comparisons can be made by making allowances for the effect of factors such as differences in climatic conditions or in levels of production output, which may affect the overall performance. In the energy-intensive industries,

where the manufacturing processes are operated at high temperatures, corrections will not be needed for differences in climatic conditions but may be needed for differences in levels of output or product mix. In other industries where the manufacturing processes involve lower temperatures, or where a high proportion of the annual energy consumption is used for space heating, corrections for differences in climatic conditions may be necessary before comparisons can be made.

An essential part of an effective M & T programme is the development of plans for further action towards the improvement of energy efficiency. Preparing these plans will be the responsibility of the Energy Coordinator or, in a large organization, the Energy Executive. When the necessary expertise is not available on site or staff resources are limited, advice may be sought from a consultant with experience of M & T systems. It will be necessary to consider the possible measures which might be taken, the financial and other resources which will be required, and the likely benefits. The plans will have to be integrated with those for other developments within the organization. Alternative options may have to be considered, and priorities will have to be set. Separate action plans are recommended (19) for the three types of measures:-

- (1) Measures which involve no capital cost. These will usually include improvements in motivation, in "housekeeping", and in working practices.
- (2) Measures involving low capital cost. These will include, for example, the installation of better control systems or improvements in insulation on steam or hot water pipes.
- (3) Measures requiring major capital investment, e.g., the installation of more efficient boilers, heat recovery systems, or new process plant.

A high priority should be given to measures in the first category. Improvements in efficiency through better energy housekeeping can be substantial. The cost savings achieved can help to finance measures involving capital expenditure and the tighter control over energy use provides a firm base line for judging subsequent improvements in the efficiency of energy use.

In considering schemes for capital investment, it should be noted that energy savings may not be additive. In the process industries, the maximum energy economies may

be achieved through process integration and the application of the principles of pinch technology (20). The lowest practicable heat requirement is established so that the heat input and capital cost of the plant can be optimised.

Proposals for measures involving capital investment should be properly presented so that they can compete with other claims on capital resources. They should include a full technical description of the project, details of the financial and other resources required, as well as forecasts of the annual savings and expenditure.

A number of methods are commonly used for the financial appraisal of projects (21). The simplest method is to calculate the payback-time — the length of time required to recover the initial investment. If the savings accrue at a steady rate, the payback-time will be obtained by dividing the forecast investment by the expected annual savings.

To decide on the payback time which indicates a worthwhile investment, the value of future savings can be discounted using a discounting rate which is comparable with the borrowing rate. Alternatively, the internal rate of return can be calculated, so that the financial benefit from the project can be compared with those from other investment opportunities.

In making plans for further action, the importance of education and training should not be overlooked. Senior management should be fully aware of what can be done to improve the efficiency of energy use, and staff at all levels should be ready to take the opportunities of making better use of the energy which is under their control. Formal training courses for Energy Coordinators and technical staff are widely available; training films for use by Energy Coordinators can be obtained from the Energy Efficiency Office; seminars, conferences and exhibitions covering different aspects of energy management are held at frequent intervals. Basic technical information is set out in simple terms in the Fuel Efficiency Booklets published by the Energy Efficiency Office (Appendix VI).

5 Benefits of M & T in practice

The results obtained from the Energy Efficiency Office programme have shown that the use of monitoring and targeting provides the following important benefits:-

1. Better control of energy use, an increased awareness of energy costs, and a greater commitment towards improving the efficiency of energy use.
2. Good energy cost information for making manufacturing and commercial decisions, and for forecasting future energy budgets.
3. Reductions in energy costs, typically about 10% and exceptionally as high as 25%, achieved by improvements in the use of energy, without significant capital expenditure and within existing workloads.
4. Better information on the ways in which the efficiency of energy use can be increased, and on the cost savings which can be made through improvements in working practices or through capital investment.
5. Further reductions in energy bills through cost-effective capital investment in measures which improve the energy efficiency of buildings, plant or manufacturing processes.
6. More reliable procedures for measuring energy cost savings and evaluating the return on energy-saving investments.

Indirect benefits from the introduction of M & T systems include the more satisfactory control of environmental conditions within buildings and, in manufacturing industry, improvements in output, products of higher and more consistent quality, and lower reject rates.

M & T can lead to the better use of energy in all sectors of the national economy. It is widely applicable throughout industry and commerce, and in all branches of the public sector. The largest cost savings are being made in the energy-intensive process industries, but the system is easily adapted to control energy use in, for example, retail shops and offices where energy costs at an individual site may be relatively small. A major clearing bank, for example, found that the M & T system it introduced in 1981, at 1,000 of its 3,000 sites, produced savings of £1 million on an annual energy bill of £6 million. A key factor in the success of this scheme was the fact that each bank site was a separate profit centre and energy savings led directly to higher profits at each individual site.

In manufacturing industry, M & T can be the key to achieving substantial energy cost savings; it provides the motivation for improvement in performance, and persuades senior management of the value of investment in improved energy efficiency.

Table 5/1 shows how companies in eight sectors of manufacturing industry improved their performance in the use of energy during the development phase of the Energy Efficiency Office programme. Typical reductions in annual energy costs ranged from 4 to 18 %. Following these successful results, promotional campaigns led to further companies adopting the M & T approach to energy management.

INDUSTRIAL SECTOR	Typical percentage reduction in annual energy costs
Bricks	5
Food	13
Iron founding	8
Non-Ferrous Metals	12
Paper and Board	9
Pottery	4
Private Steel	7
Textile Finishing	18

Table 5/1 Typical improvements in the use of energy at manufacturing sites taking part in the energy Efficiency Office programme

In some industrial sectors, schemes have been developed by Trade and Research Associations, as part of the M & T programme, for making comparisons, in confidence, between the performance of different companies manufacturing similar products. In the paper and board industry, for example, mills taking part in the M & T scheme provide the British Paper and Board Industry Federation with information on their SERs (in primary therms per gross tonne) for the manufacture of different product grades (5,19). After applying appropriate correction factors, this information can then be made available, in outline and on a confidential basis, to other mills taking part in the scheme so that a mill can make a realistic assessment of its performance in the use of energy in comparison with that of other mills making similar products. This exchange of information on SERs not only provides an incentive to improve performance but can also provide the data needed for more accurate forecasts of future energy requirements with changes in production levels or product mix.

The results achieved by the paper and board industry provide an excellent example of the success of M & T in manufacturing industry (5). In 1984, nearly 600 million therms of energy, costing over £200 million, were used by the British paper and board industry. At an average site, the annual consumption was about 5.5 million therms and the corresponding cost, about £2 million per year, represented on average, about 18% of total manufacturing costs. Starting in 1981, four mills cooperated in the development phase of the Energy Efficiency Office programme and their success led to the promotion of M & T throughout the paper and board industry. Within a year, M & T was in use at mills responsible for 25% of the industry's output; by the end of the promotional phase in 1985, half the industry had taken up M & T as an energy management system. Over the five year period, specific energy use across the whole range of products manufactured was reduced from 290 therms/tonne to 220 therms/tonne with a major part of this improvement resulting from the use of M & T. The annual energy cost savings made by the mills taking part in the Energy Efficiency Office programme reached a value of £11 million corresponding to an average reduction of 12% in the annual energy costs for each of these mills. The improvement in performance at one of the mills taking part in the programme is shown in Figure 5/1. A cost saving of £64,000 on an annual energy bill of £1.5 million was achieved in the first year of the M & T operation.

Similar progress has been made in other sectors. By 1985, sixty sites in the textile finishing industry and ten in the steel industry had each implemented the M & T system developed for its particular sector.

The potential cost savings available to UK manufacturing industry through the use of M & T can be estimated from the results of the Energy Efficiency Office programme (22). The typical energy cost reduction of 10% represents a saving of £700 million per annum on the total energy bill of £7 billion for the whole of manufacturing industry. This reduction in energy costs could be achieved within two years without major capital investment.

The greater part of the saving would come from improvements in the efficiency of energy use at the larger manufacturing sites. Analysis of the annual energy purchases of some 110,000 sites in UK manufacturing industry (Figure 5/2) indicates that most of the energy – about 90% – is used at the 2,800 larger sites each purchasing over 500,000 therms per annum. The adoption of M & T at these sites could lead to a saving of around £600 million per annum. Savings at the smaller sites would however be just as important in increasing profitability and competitiveness.

The total savings in energy costs which could be made in manufacturing industry by making full use of currently available technology have been estimated at 30%. Even with a need for a high rate of return on capital, investment of the additional profits derived through the use of M & T could quickly bring about a reduction in the total energy bill which would approach the estimated potential saving of £2 billion per annum for manufacturing industry.

Savings achieved in other sectors of the economy through improvements in energy management indicate that M & T could be one of the master keys to achieving a 20% reduction in energy use in the UK.

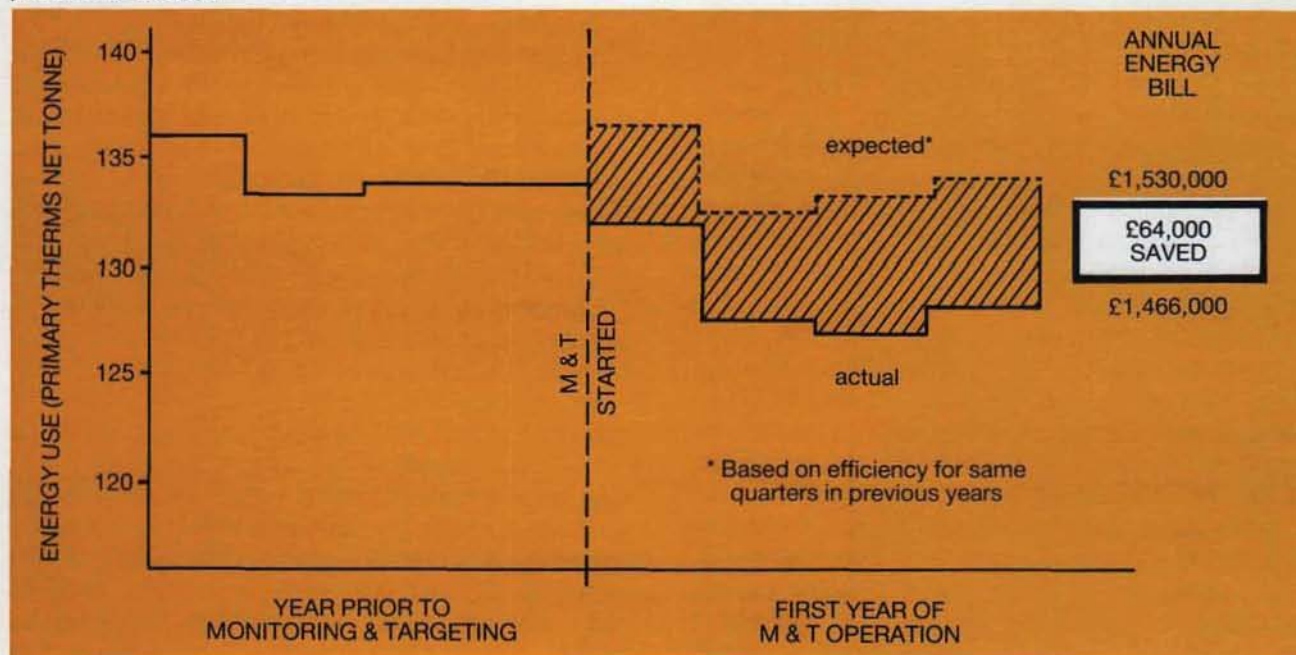


Fig. 5/1 Improvement in energy efficiency at a mill in the paper and board industry after introduction of monitoring and targeting (5)

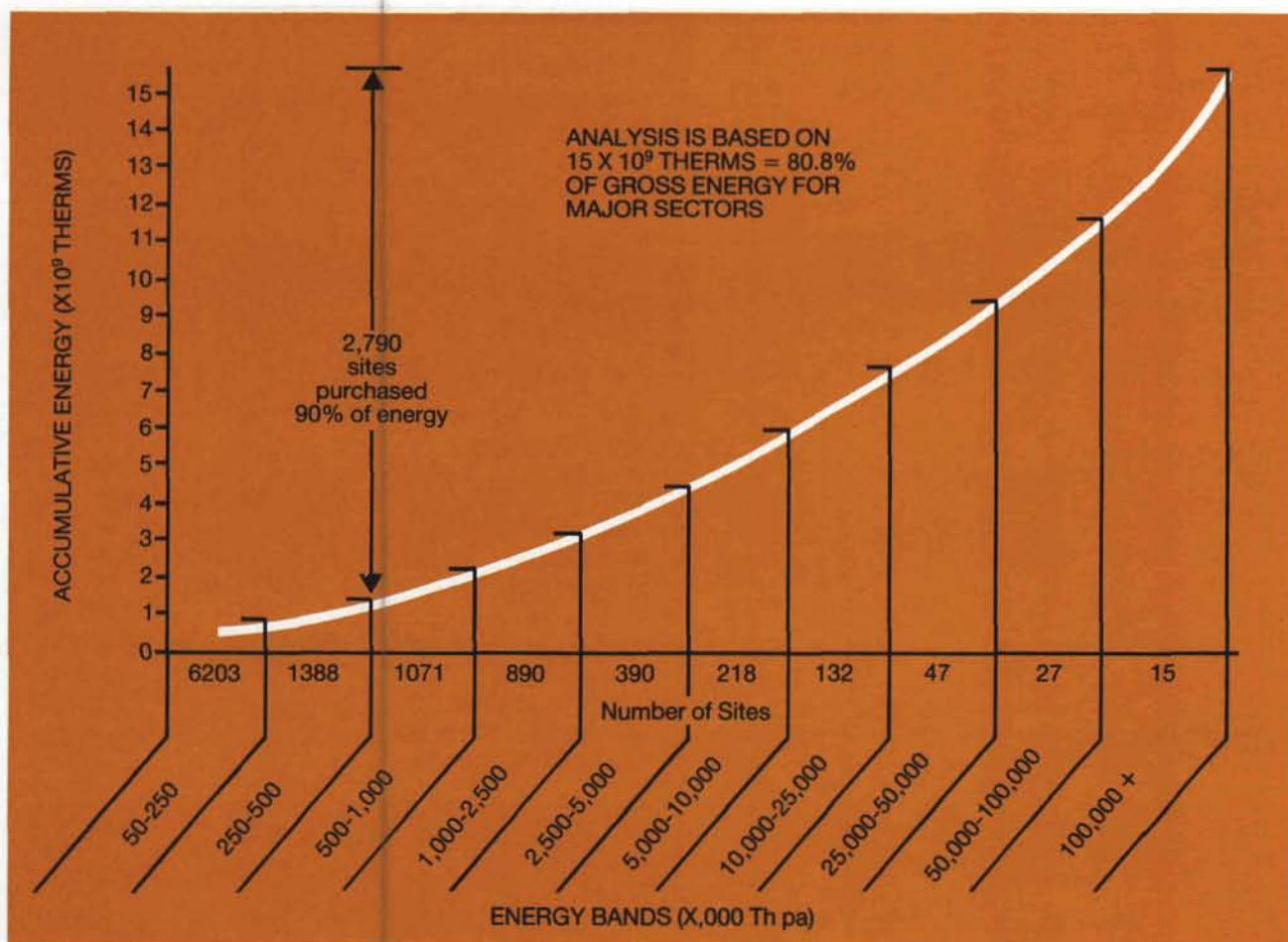


Fig. 5/2 Annual energy purchases by UK industry – cumulative energy purchases by sites in different energy bands (22)

ARCHIVED DOCUMENT

Standards

1. General Principles

In setting standards of performance for the use of energy at each energy accountable centre (EAC), account has to be taken of a range of factors or variables which lead to fluctuations in the rate at which energy is used. The **controllable variables** are those which can be regulated by management so that energy consumption is held at a level which gives the required results at the lowest overall economic cost. They include the proper operation and maintenance of plant, equipment and buildings, and the avoidance of unnecessary waste. The **uncontrolled variables** include the economic and technical factors over which the manager has no direct control and which determine the conditions under which he has to meet his objectives. For example, when energy is used for heating buildings, allowances have to be made for changes in weather conditions. In shops and stores, the number of customers per day may be important since this can affect heating requirements. In manufacturing industry, important technical variables may include the level of production, changes in the nature of the products, variations in the raw materials, reject rates and when relevant, the ratio of electricity generated in-house to that purchased. In general, every business will have its key parameters which affect energy consumption standards.

After allowing for the effects of these variable parameters, the standard should represent an efficiency of performance in the use of energy which, with some effort, can be equalled or surpassed. It is important that standards should be agreed by all concerned and that those responsible for the control of energy use should be involved in their development. Recent performance over a sufficient time interval usually provides the best basis for deciding the level at which a standard should be set. The standard can then be seen to be realistic and its relevance is understood. If limited information only is available, a provisional standard can be set and this can be refined later as more data becomes available.

A useful first step in setting a standard for an EAC is to plot the total energy used each week or each month against time over a period of 12 – 18 months. Plots of energy use for each fuel and electricity can be included and in the case of a

manufacturing process, the level of production. This can be done more easily if the values for each set of data are normalised by referring them to the first point which is given a value of unity or 100 (23). Plotting the information as indices in this way (Figure A/1) helps in identifying any anomalous results and provides a guide to what needs to be done in developing appropriate standards. Usually, the energy consumption in a given period will be found to depend on the weather conditions, the number of hours worked and, for a site in manufacturing industry, the other factors mentioned above.

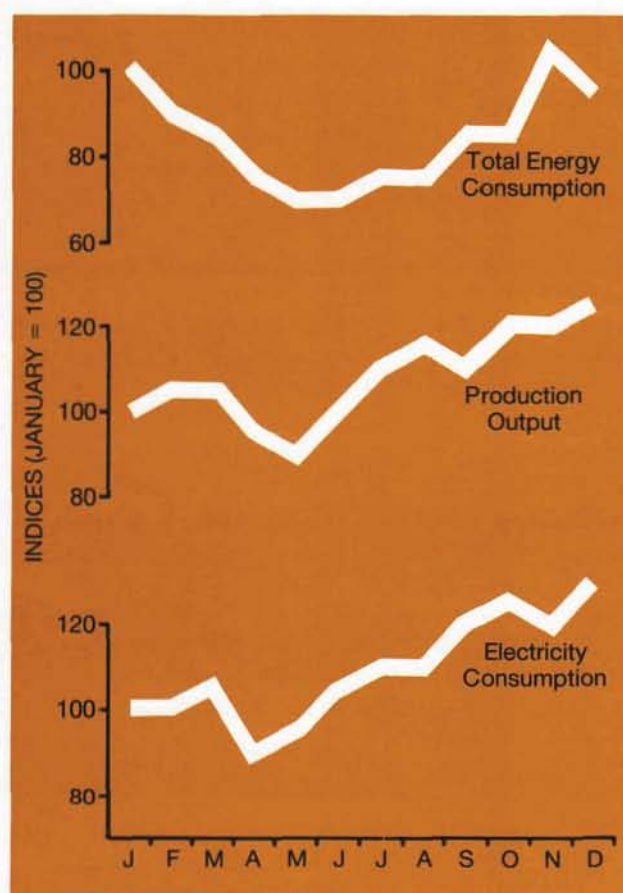


Fig. A/1 Information related to monthly energy consumption

In assessing performance for an EAC, the normal procedure is to compare the actual SER — which is of immediate significance to management — with a standard value representing the SER which would be expected after making allowance for the effect of the variable parameters. When only one variable parameter is important, setting up standards and monitoring energy use is straightforward. For example with space heating, the main variable is usually the external temperature and with most production processes it is variations in throughput.

In general, the effect of one of these variables on energy consumption can be described by a simple relationship of the type —

$$E = C + aV$$

where E is the energy consumed in a given time, C is a constant, V represents the value of the variable for the given time (e.g., the output per month) and a is a coefficient (e.g., the energy required per unit of output).

2. Effect of variations in external temperature

Changes in external temperature can have a significant influence on energy consumption in many industrial processes and will have a major effect on energy requirements for space heating.

The annual SER for space heating can be expressed in terms of the energy needed annually per unit floor area to maintain the required temperature conditions. When space heating is the major energy use, the rate at which energy is used during the third quarter (or, if information is available on a monthly basis, during July and August) can be taken to correspond with that required for purposes other than space heating. A rough estimate of the annual energy requirement for space heating can then be obtained by subtracting the annual energy requirement for purposes other than space heating from the total annual consumption. Dividing by the floor area then gives a SER space heating. The SER calculated in this way can provide a rough guide to the standard of performance but the value obtained will be approximate only since the base load may make a significant contribution to space heating during the winter months. For light industry, a better-than-average value for the space-heating energy requirement would be about 0.8 GJ/m^2 per annum, but much higher values, e.g. 5 GJ/m^2 per annum might be found at manufacturing sites where the energy efficiency is low (24).

Although SERs calculated in this way can provide a useful indication of performance they cannot be used to monitor the varying energy requirements for space heating as the weather conditions change from month to month and from year to year. To do this, some measure is needed which takes into account (a) how far the external temperature has fallen below the level at which space heating would be needed and (b) the length of time during which the external temperature has been below this base level. The measure usually employed is the "degree-day". One degree-day is accumulated when, for a period of one day, the outside temperature remains 1°C (1.8°F) below the base temperature at which no heating is required. Formulae for calculating the number of degree-days are given in Appendix IV.

A base temperature of 15.5°C is normally used since experience and tests have shown that when the outside temperature is 15.5°C , the normal activities of the occupants, solar gains and the heat given out by, for example, office equipment, usually provide sufficient heat to maintain the temperature at about 65°F (18.3°C) and no extra heating is required. Figure A/2 shows the average number of degree-days (base 15.5°C) in the Thames Valley for each month over the 20 years to 1979.

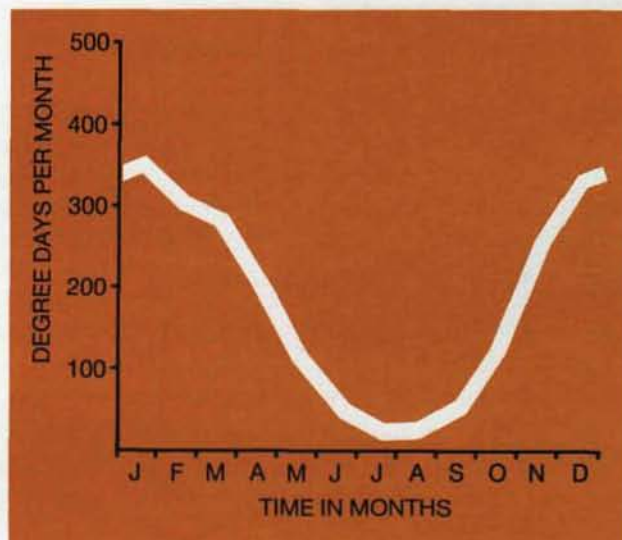


Fig. A/2 Monthly degree-days (Thames Valley)

A table giving monthly degree-days for different regions of the United Kingdom is published each month in "ENERGY Management" by the Department of Energy. Information on degree-days can also be obtained from Regional Energy Efficiency Officers. When the local climatic conditions differ appreciably from those at the nearest site for which degree-day information is available, it may be necessary to derive degree-day values from daily measurements of maximum and minimum temperatures using published tables (25) or the equation given in Appendix IV. A degree-day monitor developed by the Shirley Institute* is commercially available. This is microprocessor controlled and gives degree-day values daily with a weekly summation.

Care is necessary in using degree-days and too much accuracy should not be expected. The published monthly values are based on the assumption that the required temperature needs to be maintained within the building over 24 hours and throughout the week. It also has to be

*Manufactured by JEL Energy Conservation Services Limited, Stockport.

remembered that the outside temperature is not the only factor influencing energy requirements for space heating: wind strength and solar radiation, for example, can have significant effects. The use of daily degree-day values can give misleading results since the thermal response times for buildings will be in the order of days rather than hours; weekly values are better, but monthly values are best. A rolling 3-month average can help in smoothing out the results and in reducing the effects of any discrepancies between the periods of measurement for degree-days and energy consumption (23).

In setting standards for energy use in buildings, two procedures can be used to establish the energy requirement (26):-

(a) For **new buildings** when data on previous energy use is not available, the energy requirement can be calculated using a procedure (27) which takes into account at least the following factors:-

- (1) required environmental conditions and periods of use;
- (2) climatic conditions;
- (3) thermal transmittance of each part of the enclosure of the building;
- (4) thermal response of the building's main constructional elements;
- (5) rate of air change;
- (6) effect of glazing on lighting use;
- (7) effect of incidental gains (e.g. occupants, lighting, solar gain);
- (8) effects of shading;
- (9) effects of controls on the main energy-using services;
- (10) efficiency of the equipment.

(b) For **existing buildings**, the energy requirement can be established by direct measurement. The standard of performance in the use of energy is most easily derived by plotting monthly energy consumptions over a 12 month period against the corresponding degree-day values. If energy is used mainly or almost entirely for space heating, a plot of the type shown in Figure A/3a would be expected when the total monthly energy consumption (or monthly energy use for space heating) is plotted against monthly degree-days (25). In many buildings however, energy will also be used to meet other requirements which may be approximately constant during the year, e.g. the supply of hot water. If this base load does not make a significant contribution to space heating, the monthly energy consumption can be expected to depend on monthly degree-day values in the way shown in Figure A/3b with the intercept on the vertical axis representing the base load.

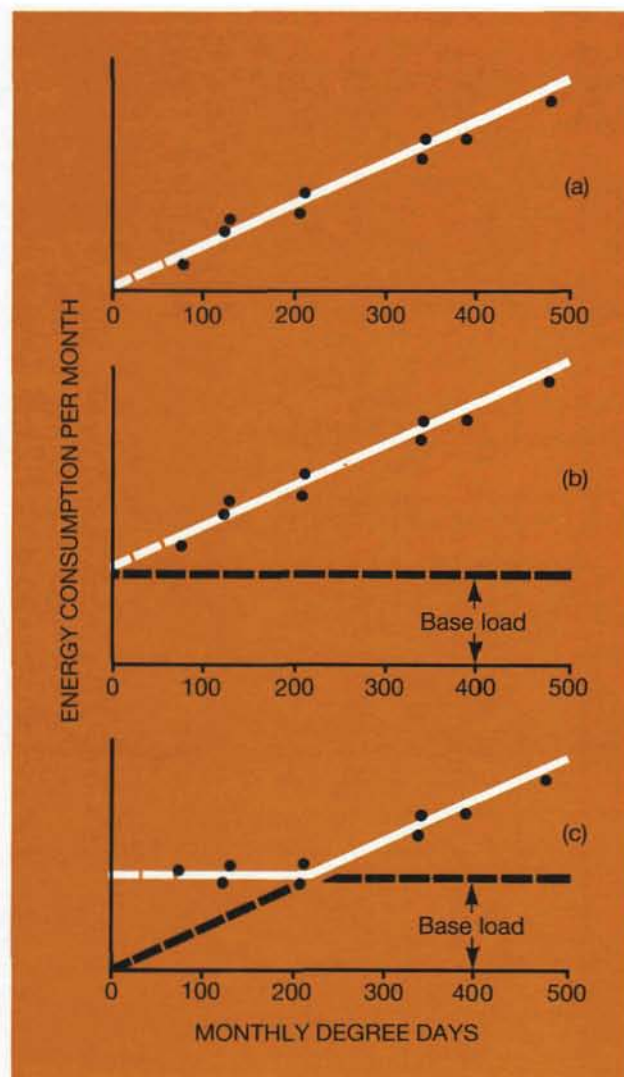


Fig. A/3 Standards for energy use in space heating

Except in special circumstances (e.g., with endothermic chemical processes), essentially all the energy expended within a building, including that used to provide lighting and power, will be dissipated as heat. If this heat is not removed from the building, through increased ventilation or by, for example, the discharge of hot gases or hot liquid effluents, then the base load may contribute to space heating requirements in the colder weather. The relationship between total energy consumption per month and monthly degree-days can then be expected to take the form shown in Figure A/3c.

In all three Figures, the slope of the line derived from the values for energy consumption when space heating has to be provided will represent the heating efficiency in energy consumption per degree-day. If this is expressed in GJ/m^2 degree-day the value obtained can be used to compare space-heating performances in different buildings in different parts of the country. To monitor and control energy use, however, the line of best fit will represent the standard with which actual values can be

compared. The energy consumption during a given month should be close to and preferably less than that for the corresponding degree-day value.

In the M & T system developed for use by Local Authorities, the actual monthly energy consumptions (after deducting the base load) are normalised to give the energy consumptions which would be expected on the basis of the 20-year average for the monthly degree-day value for the region. This normalised energy consumption can then be used to make comparisons between performance in one year and the next.

3. Effect of variations in level of output

When the energy used in a manufacturing process during a given period is plotted against the corresponding output, an approximately linear relationship of the type shown in Figure A/4 is frequently obtained. Relationships of this kind are often found for energy use in process plant, e.g. furnaces and ovens, when the plant is in continuous or semi-continuous operation and the throughput varies, or when the load varies in a batch process but the other operating conditions remain constant.

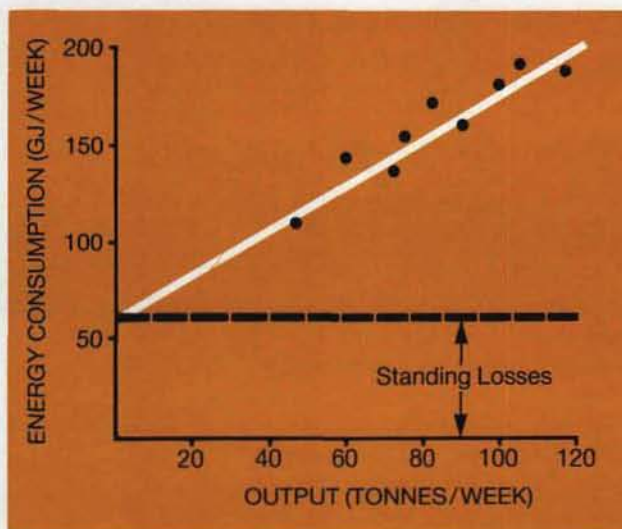


Fig. A/4 Effect of level of output on energy consumption

The weekly energy consumption given by the intercept on the vertical axis corresponds to the standing losses. The slope represents the energy needed per unit of output in carrying out the process itself. If a material is being dried, the slope would be expected to correspond with the energy needed to heat up the material and evaporate the water from unit weight of product.

The corresponding relationship between the SER and the level of output is shown in Figure A/5.

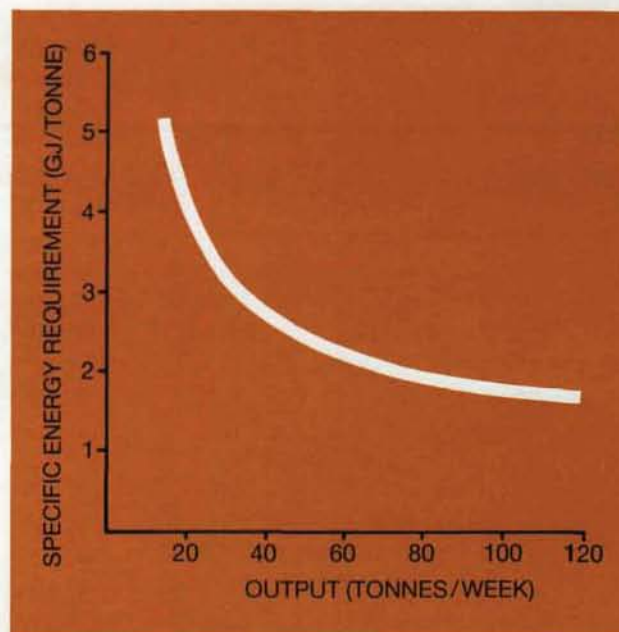


Fig. A/5 Effect of level of output on specific energy requirement

The curve rises sharply at low levels of output where the effect of the standing losses is much more significant. To obtain the relationship between SER and output which provides the standard of performance, data collected over a sufficient period is plotted as shown in Figure A/4 and the line of best fit is found by inspection or regression analysis. The corresponding values for the SER can then be calculated from the linear relationship to give the curve shown in Figure A/5.

4. Effect of variations in both external temperature and level of output

In many of the process industries, energy use will depend on both the external temperature and the level of output. Consequently there will be a seasonal variation in energy use as shown for a UK paper mill in Figure A/6 (5). In setting standards of performance, a correction factor for the level of output can be estimated by plotting weekly energy use against output for a one year period to give a band of points as shown in Figure A/7. The slope of the band gives the correction factor for the level of output. An approximate correction factor for the external temperature can be derived from the height of the band at a fixed output and the corresponding range in the average external temperature. Alternatively, an approximate correction factor can be obtained by plotting the SER against time as shown in Figure A/6 and then comparing the difference between the highest and lowest values with the corresponding spread in the average value for the external temperature (28).

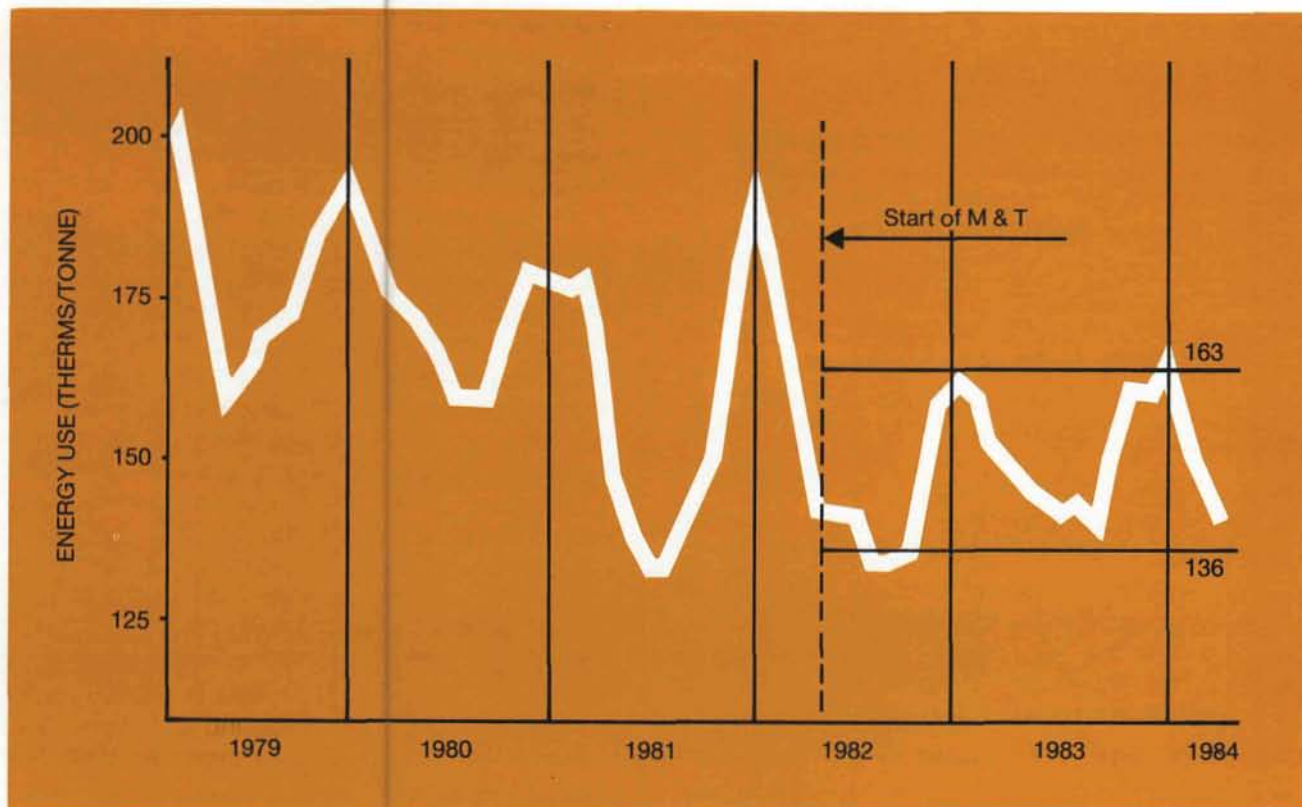


Fig. A/6 Seasonal variation in energy use at a paper mill (5)

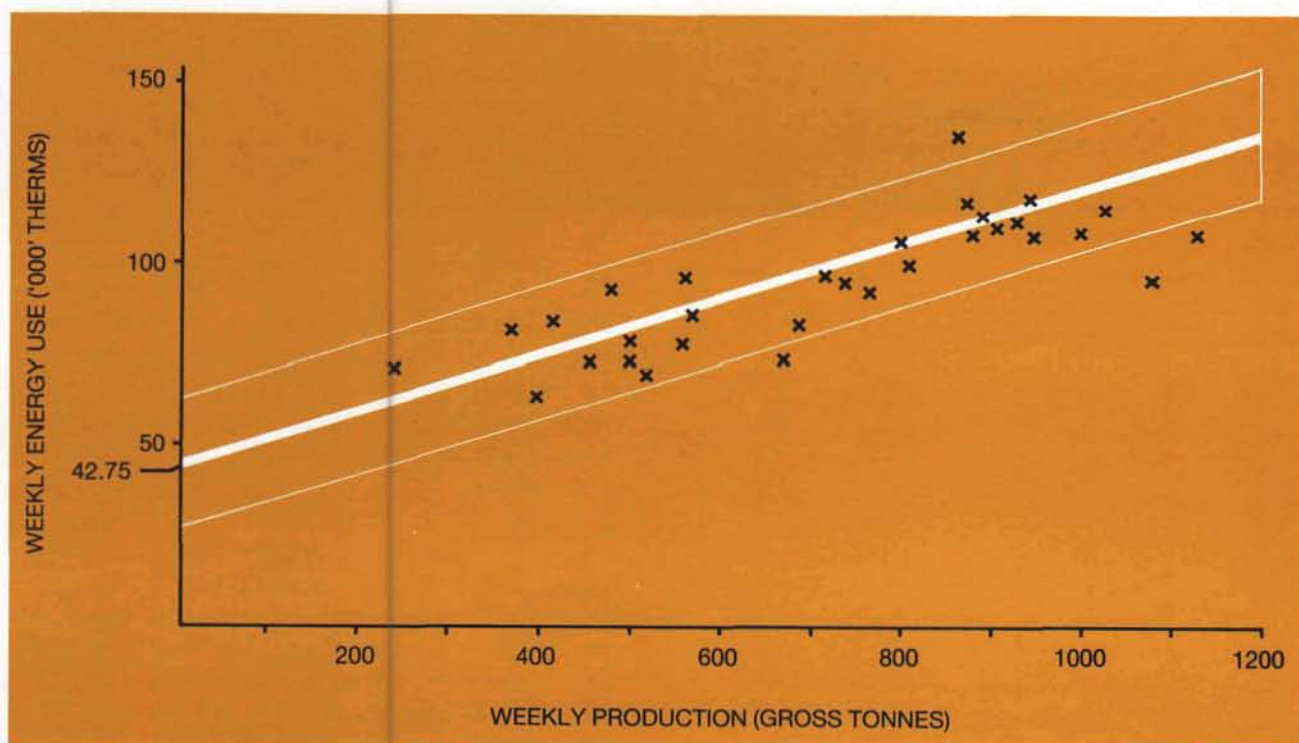


Fig. A/7 Effect of variations in external temperature and level of output on energy use at a paper mill (5)

5. Model systems and multivariate regression analysis

At many industrial sites, the products and manufacturing processes may be diverse, there may be frequent changes in the pattern of production, and separate metering of the energy used in each of the different activities may be impracticable. This will often be the case when steam is used in a number of different processes.

Standards of performance can however still be derived by developing simple mathematical models for the use of fuel and electricity by each EAC. The models are built up by deriving relationships between energy consumption and measured values for production output or some other indicator of the results achieved.

The manufacture of two products provides a simple example. If the only important independent variables are the production outputs for each product, then the energy consumption in a given time will be,

$$E = (C_1 + aV_1) + (C_2 + bV_2)$$

where C_1 , C_2 , a and b are constants and V_1 and V_2 represent the output of each product during the given period. The values of the constants may be obtained by analysing data collected when only one product was being manufactured, by experimentation, by calculating the theoretical energy requirements, or by regression analysis of historical data. When the constants have been obtained, the SER for a mixture of products is easily calculated.

If there are a number of unmetered processes, a similar approach can be adopted. A classic example (29) is the development of a standard heat requirement for a laundry (Table A1). The heat requirements for the various stages were calculated from the quantities of water used and the operating temperatures. Available data on the performance of the equipment was used to estimate the heat needed for drying. Space

Process Stage	Specific Heat Requirement (Btu/lb dry laundry)
Cotton washing	1,977
Wool washing	160
Contact driers	1,288
Air driers	309
Power	502
Space heating:	
Ventilation	638
Building loss	823
Total	5,497

Table A1 Heat requirements for a laundry (29)

heating requirements were calculated from estimates of the heat lost by ventilation and by thermal conduction through the building fabric.

In the discrete modelling approach for use in the soft drinks industry (30), a separate set of models is built up for each EAC. Each of these sets includes a model for the energy consumption corresponding to each of the measured energy inputs. The process is broken down into a number of discrete stages (e.g., bottle washing, filling, labelling, etc.) and simple models are constructed for each stage from a knowledge of the performance of the plant and its method of operation. In these models, energy use is related to the throughput or some indicator of the results achieved. Key parameters used for assessing steam use in the various processes and the methods employed for establishing the specific steam requirements are listed in Table A2. Similar models are constructed for the other energy inputs to each EAC, and these are then combined to provide models representing energy use within each EAC and in the factory as a whole. The energy consumptions predicted by these models are then compared with actual values. Precise agreement is unlikely, but it should be possible to refine the models to give results which are within $\pm 5\%$ of the actual values. When the models have been shown to be valid, energy consumptions calculated using the models provide standards of performance for each EAC and for the factory as a whole.

The effort needed in setting up a discrete modelling system can be considerable but a clear understanding of energy use is obtained, and worthwhile opportunities for energy saving are likely to be identified. Once the relationships between the key variables and energy use have been established, the effort involved in running the system will be less than might be expected since information on the values for many of the key variables will be available from production records. Further advantages of the discrete model approach are that adjustments are easily made if the pattern of production changes, and the information obtained can provide a sound basis for costing energy use in the different manufacturing processes.

A disadvantage of the discrete model approach is the likely difficulty in setting up models which accurately represent performance. When the same energy source is used to provide heat for the manufacturing processes and for space heating during the winter months, it may be difficult to devise a model which represents the additional energy requirement for space heating. Errors in developing a model from discrete elements will also be cumulative and care has to be taken that proper allowances are made for heat transferred

Plant Item	Key Variable	Method of Determining Specific Demand	
		1st Choice	2nd Choice
Flash pasteuriser	Volume processed	Direct measurement	Heat balance
Bottle/Crate washer	Number of containers washed	Direct measurement	Manufacturer's data
Carbon dioxide vapouriser	Carbon dioxide consumption	Manufacturer's data	
Distribution losses	Hours in use	Experimentation	

Table A2 Discrete models for steam demand in a soft drinks factory (30)

from one part of a process to another. Sub-metering should be preferred whenever its cost can be justified.

An alternative to the discrete model approach is the development of a single mathematical model which represents the use of energy within an EAC or in a site as a whole.

At a manufacturing site, for example, the total energy consumption in a month might be expected to be represented by an equation of the form,

$$E = C + aH + bW + cD$$

where E is the total energy consumption, H represents the hours worked, W is production output, and D is the number of degree-days, all on a monthly basis. C is a constant and a, b, and c are coefficients which have to be determined.

When energy is used to provide heat for processes operated at moderate temperatures (e.g. up to about 200-300°C), the external temperature can be expected to have an appreciable effect on the energy requirement for the manufacturing process. Additional terms may then have to be added to allow for the combined effect of external temperature and other variables. The equation can then take the form,

$$E = C + aH + bW + cD + eDH + fDW$$

where e and f are additional coefficients. Relationships of the type represented by these two equations have been used successfully for the analysis of energy use in factories (23) and in the textile finishing industry (31).

The best values for the coefficients are found by comparing actual energy consumptions with values calculated from corresponding data on the variable parameters collected over a period of at least 12 months and preferably 2 years. Multivariate regression analysis is used to find the values for the coefficients which give minimum error between the actual energy consumptions and those calculated from the equations. Care is needed in the use of this procedure: there will be a measure of uncertainty in the coefficients, statistical confidence testing may show some have to be dropped, and the analysis will have to be repeated until every coefficient is significant. The use of a computer is essential.

Once the validity of the model has been established, checking performance against the standard should be reasonably straightforward. A new standard will however have to be developed if there is a significant change in the manufacturing processes or pattern of production.

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Targets

As shown in Figure B/1, a target represents a planned improvement in performance over the existing standard. Progress towards the target is monitored by comparing the actual energy requirement with the target value. When the

required level of performance has been achieved and sustained, the target may well become the new standard.

The initial target can be the consistent achievement of the standard performance or it can be based on previous results which were better than the average. In the clay brick industry, the modal value of the weekly energy requirement has been recommended (10) as a first target (Figure B/2). The aim is then to ensure that this value is not exceeded even occasionally.

At a small site, plans for improvement in the

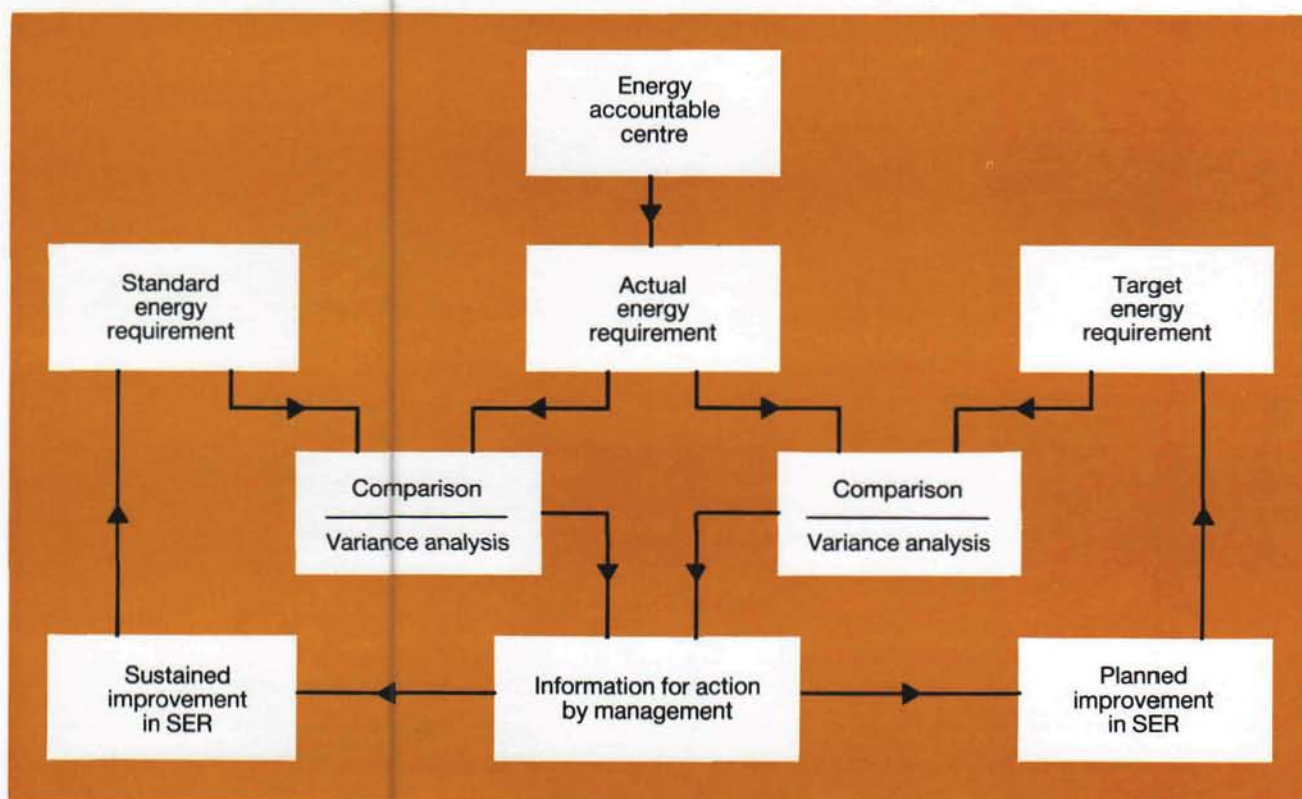


Fig. B/1 Planned improvement in performance through setting targets

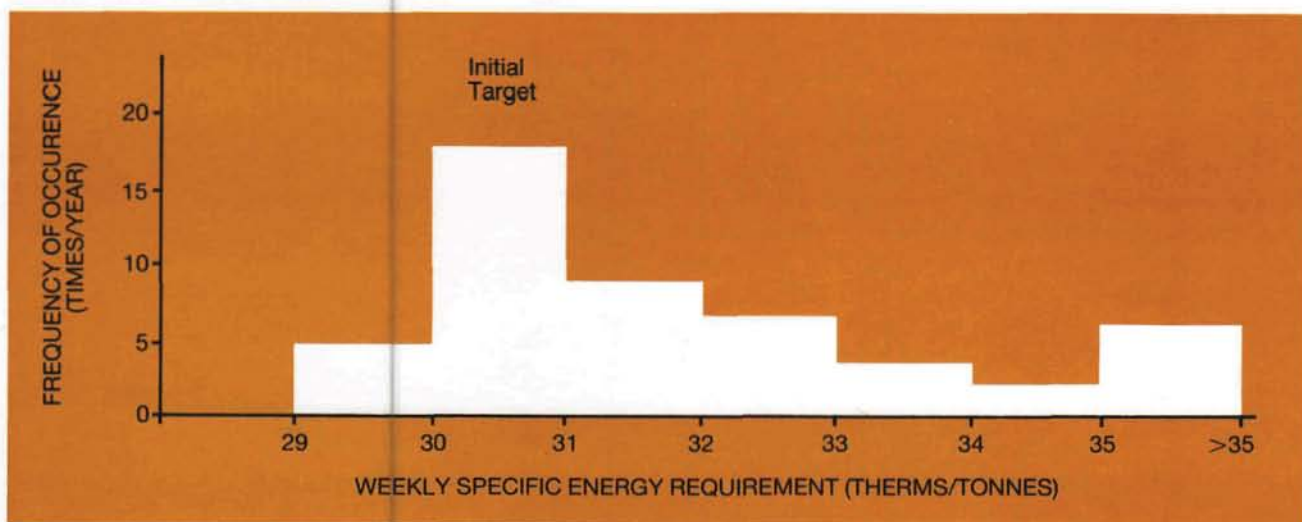


Fig. B/2 Weekly specific energy requirement at a works in the clay brick industry

efficiency of energy use may be prepared by the Energy Coordinator and then submitted for approval by senior management. When the necessary expertise is not available on site, or staff resources are limited, advice may be sought from an energy consultant with experience of M & T systems. The costs and benefits of implementing plans for improvement should be assessed and if capital expenditure will be required, account should be taken of investment criteria, the availability of capital, and the time required for payback. At larger sites in manufacturing industry, proposals prepared by the production or engineering departments will be considered by the Energy Executive. Targets may be set for each EAC and for the manufacturing site as a whole.

- better control of heating systems,
- reduction of unnecessary ventilation,
- more efficient heating systems,
- improved insulation of the buildings.

When the potential costs and benefits have been assessed, appropriate measures can be selected, and successive targets set for the improvement of space-heating efficiency. Little or no capital expenditure may be required in meeting the initial target which could, for example, as shown in Figure B/4, be a 5% reduction in the monthly energy requirement during the colder months, through avoiding unnecessary heating or the reduction of unnecessary ventilation.

When electricity is the main source of energy

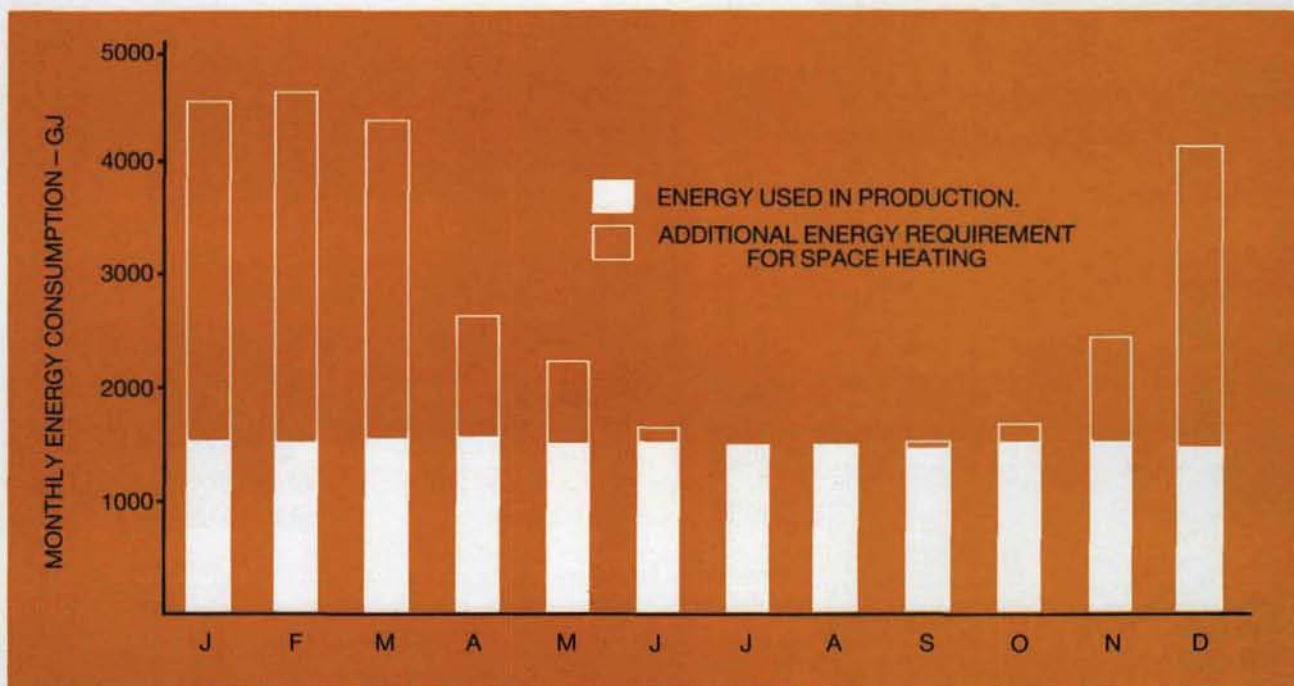


Fig. B/3 Monthly energy consumption at a factory in light industry

Diagrams or graphs showing the effect of factors such as seasonal variations in temperature, or changes in the level of output on energy consumption, can often provide a useful guide to possible further improvements. These relationships will usually have been established through the development of standards. For example, the monthly energy consumption for a factory in light industry may vary during the year in the way shown in Figure B/3 (32). The corresponding relationship between monthly energy consumption and monthly degree-days will then take the form shown in Figure B/4. The slope of the line of best-fit will correspond with the energy required per degree-day for space heating and the intercept on the vertical axis with the monthly energy requirement for production.

Measures which can be taken to reduce the slope of the line will include:

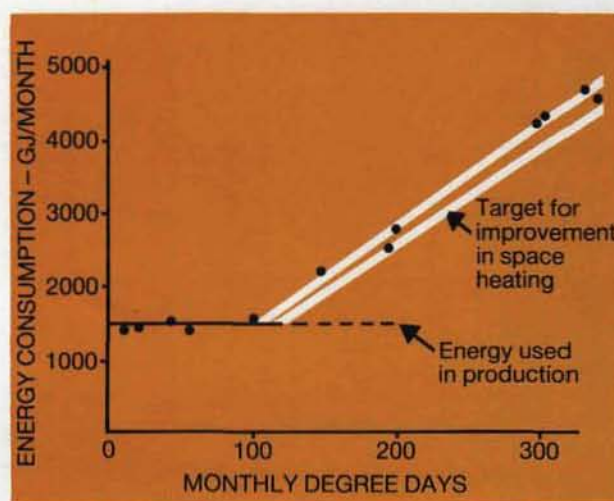


Fig. B/4 Energy use at a factory in light industry

used in production, a linear relationship of the form shown in Figure B/5 can be expected between monthly electricity use and monthly output (32). The slope of the line represents the quantity of electricity used per unit of output and the intercept represents the "standing losses" which are largely independent of the level of production. The corresponding relationship between the quantity of electricity used per unit of production (the specific electricity requirement) and output is shown in Figure B/6. Lower values for the specific electricity requirement will be achieved at higher levels of output.

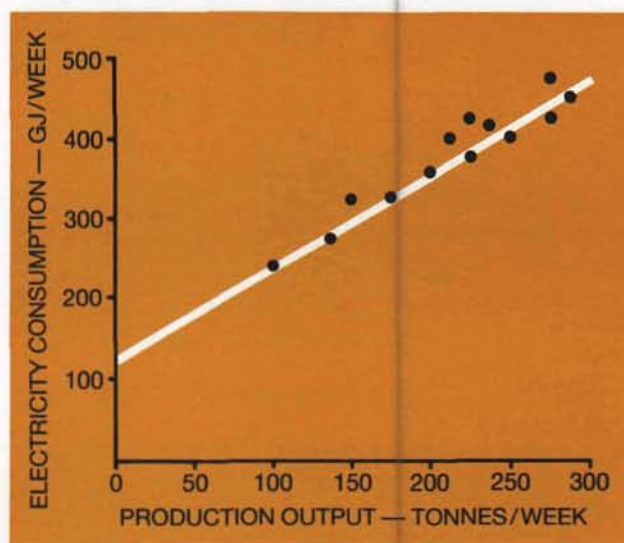


Fig. B/5 Electricity use in production

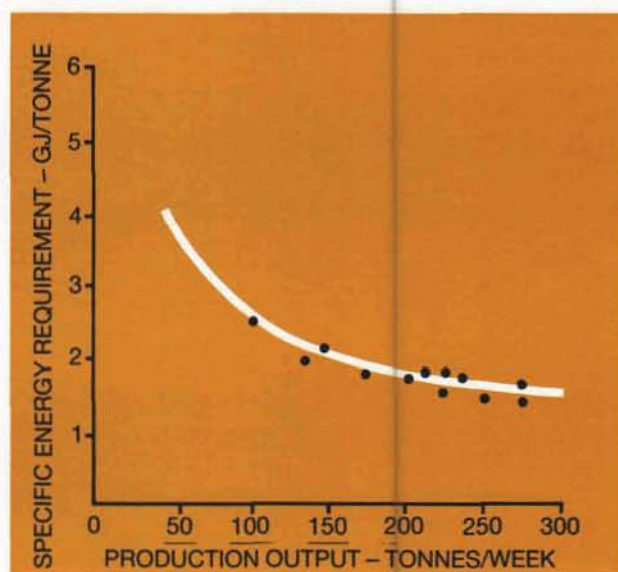


Fig. B/6 Electricity use in production – specific electricity requirement

Similar relationships between energy consumption and output are found for individual items of manufacturing plant when energy is used to provide heat, e.g. furnaces, kilns and ovens. If the item of plant corresponds with an EAC, information on the relation between energy

use and production output will have been obtained in the development of standards. If the information is not already available, a portable energy monitor can be used to establish the relationship between gas or electricity consumption and throughput (33).

The SER will be reduced by making sure that the throughput is maintained at a high level, whenever possible, by appropriate scheduling. Other opportunities for improving the efficiency of energy use will include:

- increasing insulation to an economic level,
- improving combustion efficiency,
- more efficient plant,
- heat recovery,
- changing the process.

The initial target can be based on improvements in operating practice which involve little or no capital expenditure. Some capital expenditure will be required for better insulation and significant expenditure will usually be needed for heat recovery.

Plant and equipment used in the provision of services should also be used to the best effect and standing losses reduced as far as possible. In many batch-type process industries, demands for steam and other services may vary in a step-wise manner. Plant and equipment suited to these varying demands should be used wherever possible and operated in such a way that standing losses are kept to a minimum. This is especially important with multi-boiler installations.

When, for example, electricity is used for lighting and in the provision of compressed air, opportunities for reducing the standing losses may include:

- more efficient lighting,
- better switching arrangements,
- better compressor controls,
- curing air leaks.

When the opportunities have been assessed, targets can be set, and progress towards the new level of efficiency monitored. An example is the use of successive targets to improve the energy efficiency of a furnace in a manufacturing plant (22). The weekly energy consumption was plotted against the weekly production output and the line of best-fit drawn through the points corresponding to the recent results was accepted as the standard (Figure B/7). The initial target represented by line A was set for a six-month period on the basis of equalling or surpassing the standard through close attention to weaknesses in operating practice which had previously led to large deviations from expected values.

Subsequent results showed that Target could not only be attained but that on one occasion a particularly good performance had been achieved. The reason for the better performance was identified through an analysis of the operating records and it was agreed to aim for Target B, a line drawn through this "best practice" point. Performance over the next six months showed a progressive reduction in the therms per tonne at all throughputs. At the end of

the first year, a line close to that representing Target B was agreed as the new standard. Target C represented the improvement which would be expected through the introduction of heat recovery on the furnace equipment. It was recognised that this target would only be consistently achieved after a long settling-down period involving possible readjustment of operating and control procedures. It remained as the target for a further twelve months.

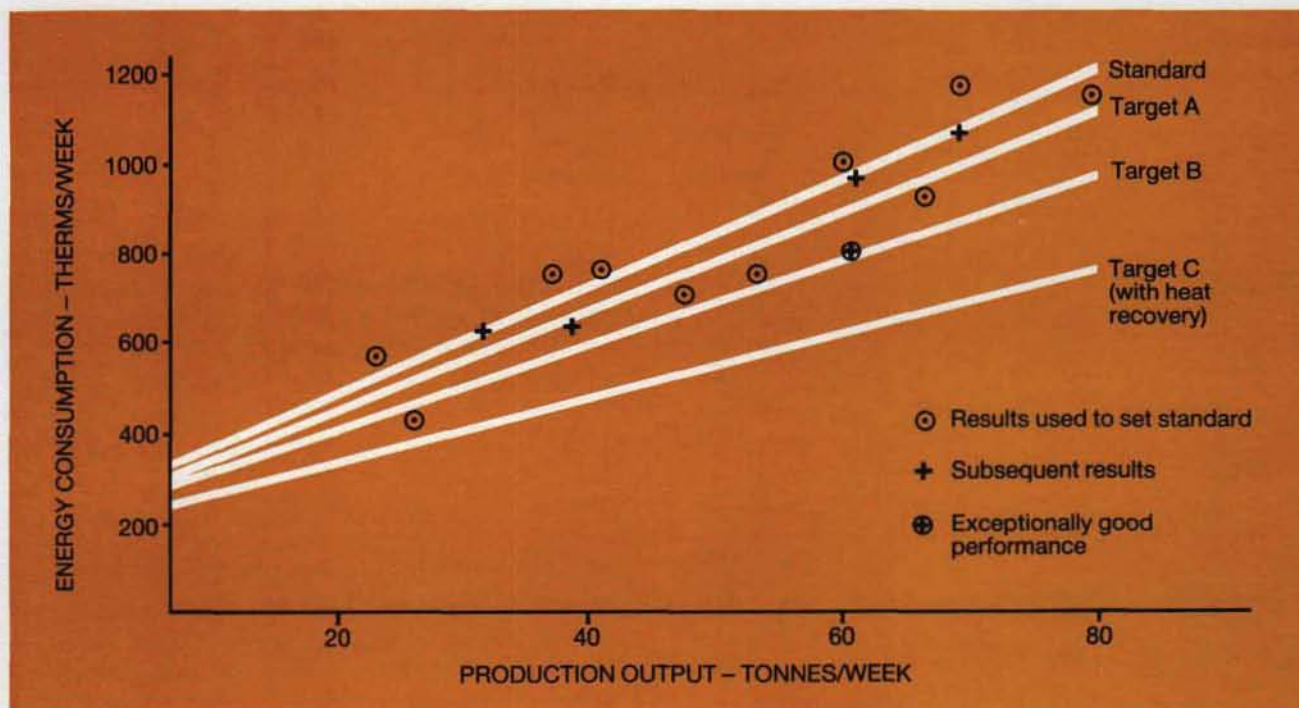


Fig. B/7 Energy requirement targets for an industrial furnace

APPENDIX I

Commonly Used SI Units

Basic SI Units

<i>Physical quantity</i>	<i>Unit</i>	<i>Symbol</i>	
Length	metre	m	
Mass	kilogramme	kg	
Time	second	s	
Electric current	ampere	A	
Temperature	kelvin	K	

Derived SI Units

<i>Physical quantity</i>	<i>Unit</i>	<i>Symbol</i>	<i>Definition</i>
Energy	joule	J	$\text{kgm}^2\text{s}^{-2}$
Force	newton	N	$\text{kgms}^{-2} = \text{Jm}^{-1}$
Power	watt	W	$\text{kgm}^2\text{s}^{-3} = \text{Js}^{-1}$
Electric charge	coulomb	C	As
Electric potential difference	volt	V	$\text{kgm}^2\text{s}^{-3}\text{A}^{-1} = \text{WA}^{-1}$

Prefixes for SI Units

<i>Prefix</i>	<i>Symbol</i>	<i>Factor</i>	
tera	T	10^{12}	
giga	G	10^9	
mega	M	10^6	
kilo	k	10^3	
milli	m	10^{-3}	
micro	μ	10^{-6}	

APPENDIX II

Conversion of Energy Units

Conversion of commonly used energy units to equivalent values in SI units

Unit	<i>Equivalent SI Values</i>		
	kJ	MJ	GJ
British thermal unit (Btu)	1.055	1.055×10^{-3}	1.055×10^{-6}
therm	105.5×10^3	105.5	105.5×10^{-3}
kilowatt hour (kWh)	3.6×10^3	3.6	3.6×10^{-3}
kilocalorie (kcal)	4.187	4.187×10^{-3}	4.187×10^{-6}
horsepower hour (hph)	2.685×10^3	2.685	2.685×10^{-3}
	W	kW	MW
British thermal unit/hour (Btu/h)	0.2931	0.2931×10^{-3}	0.2931×10^{-6}
therm/hour	29.31×10^3	29.31	29.31×10^{-3}
horsepower (hp)	745.7	0.7457	0.7457×10^{-3}

Conversion of SI energy units to equivalent values in commonly used units

<i>SI Unit</i>	<i>Equivalent Value in Commonly Used Units</i>				
	Btu	therms	kcal	kWh	hph
kilojoule (kJ)	0.9478	9.478×10^{-6}	0.2398	0.2778×10^{-3}	0.3725×10^{-3}
megajoule (MJ)	947.8	9.478×10^{-3}	239.8	0.2778	0.3725
gigajoule (GJ)	947.8×10^3	9.478	239.8×10^3	277.8	0.3725×10^3
	Btu/h	therms/h	hp		
watt (W)				34.12×10^{-6}	1.341×10^{-3}
kilowatt (kW)				34.12×10^{-3}	1.341
megawatt (MW)				34.12	1341

APPENDIX III

Typical Gross Calorific Values for Commercial Fuels

Gaseous fuels

	Gross calorific value (1)	
	MJ/kg	MJ/m ³
Natural gas	—	38.6 – 39.0
Commercial propane	50.0	93.1
Commercial butane	49.3	121.8

Liquid fuels

	Gross calorific value	
	MJ/kg	MJ/l
Kerosene	46.2	37.2
Gas oil	45.4	38.8
Light fuel oil	43.2	41.5
Medium fuel oil	42.8	41.9
Heavy fuel oil	42.5	42.0

Coal (2)

Region	Average gross calorific value (as received basis)	
	MJ/kg	
	Washed singles	Washed smalls
Scotland	28.80	27.30
North East	27.94	25.88
Yorkshire	29.68	26.74
West	30.48	27.96
Midlands	28.72	27.14
South Wales	28.12	29.40
National average	29.14	27.44

Other Solid Fuels

	Gross calorific value
	MJ/kg
Coke	28.1
Coke breeze	24.8

Notes:

1. In calculating gross calorific values, it is assumed that any water vapour is fully condensed and its latent heat recovered. Calorific values for gases by volume are referred to STP (60°F or 15.6°C and 30" Hg or 1.016 bar).

2. Values given for typical industrial fuels are for guidance only. For actual values for fuel supplied, reference should be made to local NCB Sales Office.

APPENDIX IV

Calculation of Degree-Day Values

The degree-day values published by the Department of Energy are estimated from daily measurements of maximum and minimum temperatures using the three formulae given below. The first formula is used when, during the day, both the maximum temperature (T_{\max}) and the minimum temperature (T_{\min}) are below the base temperature (T_o). In this case, the daily degree-day value is given by the difference, in $^{\circ}\text{C}$, between the base temperature and the average of the maximum and minimum temperatures. The second formula is used when ($T_{\max} - T_o$) is less than ($T_o - T_{\min}$) and the third when ($T_{\max} - T_o$) is greater than ($T_o - T_{\min}$). The base temperature at which no heating is required is usually taken as 15.5°C . Weekly and monthly degree-day values are obtained by summing the daily degree-day values.

Case 1

$$T_{\max} < T_o, T_{\min} < T_o \quad D = T_o - 1/2(T_{\max} + T_{\min})$$

Case 2

$$(T_{\max} - T_o) < (T_o - T_{\min}) \quad D = 1/2(T_o - T_{\min}) - 1/4(T_{\max} - T_o)$$

Case 3

$$(T_{\max} - T_o) > (T_o - T_{\min}) \quad D = 1/4(T_o - T_{\min})$$

D = Daily degree days

T_o = Base temperature ($^{\circ}\text{C}$)

T_{\max} = Maximum external temperature ($^{\circ}\text{C}$)

T_{\min} = Minimum external temperature ($^{\circ}\text{C}$)

APPENDIX V

Publications in the Industrial Energy Thrift Scheme Series

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4	Shipbuilding and marine engineering	32	Meat, fish, fruit and vegetable processing
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14	Electrical engineering	42	Milling, mixing and edible fat processing
15	Timber, furniture and related industries	43	Paint manufacture
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22	Footwear, leather and fur	50	Instrument engineering
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25	Cans, cutlery, engineers' small tools, hand tools, nuts, bolts, wire and wire products	54	Tractors and cycles
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- 3 Economic use of fixed space heaters for industry and commerce
- 4 Compressed air and energy use
- 5 Steam costs and fuel savings
- 6 Recovery of heat from condensate, flash steam and vapour
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- 10 Controls and energy savings
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- 13 The recovery of waste heat from industrial processes
- 14 The economic use of oil-fired boiler plant
- 15 The economic use of gas-fired boiler plant
- 16 Economic thickness of insulation for existing industrial buildings
- 17 The economic use of coal-fired boiler plant
- 18 Boiler blowdown
- 19 Process plant insulation and fuel efficiency
- 20 Energy efficiency in road transport

Copies of these booklets may be obtained free of charge from:

The Energy Efficiency Office
Department of Energy
Thames House South
Millbank
London SW1P 4QJ

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Paper 15, Proceedings of 1985 Annual
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Definitions

ENERGY ACCOUNTABLE CENTRE (EAC)

An identifiable area of activity within which an individual can be held responsible for measured energy use. It should correspond with an existing cost centre or group of cost centres.

ENERGY CONSUMPTION

The quantity of energy used in recognized units (eg GJ, kWh or therms). It may be expressed in terms of the quantities derived from particular energy sources (eg individual fuels or electricity) or as a total.

ENERGY REQUIREMENT

The energy consumed to achieve a specified result. It may be the energy derived from a particular energy source or the total energy used.

SPECIFIC ENERGY REQUIREMENT (SER)

The SER is the key indicator which relates energy consumed to unit measure of the results achieved.

ENERGY STANDARD

The expected energy requirement or expected specific energy requirement under given conditions after allowances have been made for the effects of recognized variables, eg weather conditions or variations in the level of production output.

ENERGY TARGET

A reduction in the energy requirement or specific energy requirement which is to be achieved within a given time through planned actions to improve the efficiency of energy use.



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